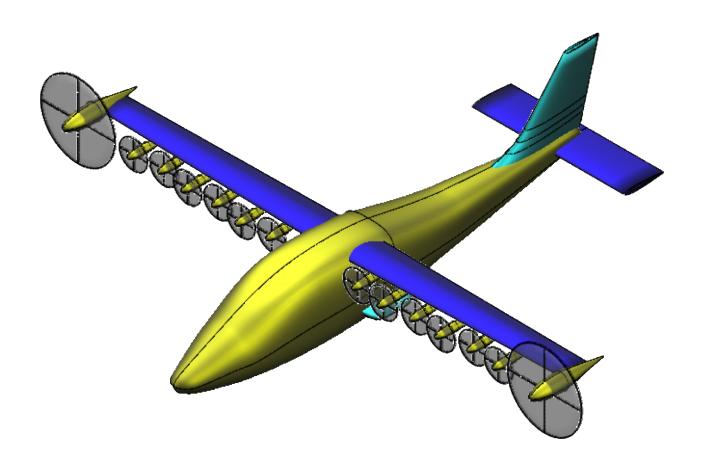
Convergent Aeronautics Solution (CAS)

Scalable Convergent Electric Propulsion Technology and Operations Research (SCEPTOR)



Preliminary Design Review

November 12-13, 2015

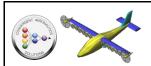
Day 2 Package



Agenda Day 1



Section	Presenter	Time Slot (PST)
Ground Rules	CJ Bixby (Board Chair)	8:00 - 8:15
Project Overview	Mark Moore/Tom Rigney	8:15 – 9:00
Phase I Flight Test Overview	Tim Williams	9:00 – 9:30
System Overview	Matt Redifer	9:30 – 10:00
Vehicle IPT	Matt Redifer	10:00 - 11:00
Lunch		11:00 - 12:00
Flight Control IPT	Dave Cox	12:00 – 1:00
Piloted Simulation Development	Bruce Cogan	1:00 - 1:30
Power IPT	Sean Clarke	1:30 – 2:30



Agenda Day 2



Section	Presenter	Time Slot (PST)
Performance IPT	Nick Borer	8:00 – 9:00
Wing IPT	Jeff Viken	9:00 – 10:30
Instrumentation IPT	Ethan Nieman	10:30 – 11:30
Lunch		11:30 - 12:30
T&V Planning	Yohan Lin	12:00 – 12:30
Flight Operations Overview	Aric Warner	1:00 - 1:30
Hazard Review	Phil Burkhardt	1:30 - 2:00
Wrap-up / RFAs	CJ Bixby	2:00 – 2:30

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Agenda 2





Performance & Sizing IPT

Nick Borer nicholas.k.borer@nasa.gov (757) 864 4818



Entry Criteria



Subsystem Level Entry Criteria	Evidence
Technical Performance Metrics (TPMs)	Slide 30
Preliminary Subsystem Requirements and/or Specifications	Slides 6-10
Draft Interface Control Documents	Slides 11-12
Design and Analysis	Slides 17-27
Drawing Tree	N/A*
Test and Verification Planning	Slides 38-42

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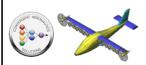
Roles & Responsibilities



- Initial sizing of SCEPTOR across Phase II-IV configurations
- Performance analysis & verification
- Cooling system analysis & design
- Team:
 - LaRC: Nick Borer, (Michael Patterson), Joe Derlaga, Brandon Litherland
 - GRC: Bob Christie
 - Joby: Alex Stoll, (Arthur Dubois)

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Performance & Sizing IPT 3



Schedule to CDR



Removed

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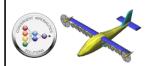
Document Status



Doc No.	Doc Type	Document Title	Status
CEPT-REQ-003	Req	Performance and Sizing Subsystem Requirements Document (SSRD)	Draft

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Performance & Sizing IPT 5



Requirements (1)



System Req No.	System Requirement Description	Subsystem Req No.	Subsystem Requirement Description	Verif. Method
	The CEPT system	S1.1	The SCEPTOR Sizing and Performance design high lift motor operating stall speed in the landing configuration, VS0hl, shall be no greater than 55 * sqrt(MTOW/1230) KCAS, where MTOW is the maximum takeoff mass in kilograms.	Analysis
1	shall establish a General Aviation	\$1.2	The SCEPTOR Sizing and Performance value for steady climb gradient shall be at least 6.7 percent at a climb speed of 1.2*VS1.	Analysis
1	(GA) baseline as the performance metric.	\$1.3	The SCEPTOR Sizing and Performance design energy consumption rate per unit distance at the cruise condition shall be at least 3.5 times lower than the energy consumption rate per unit distance of the baseline aircraft at its maximum cruise power setting (recommended mixture and appropriate cruise weight) at the specified CEPT cruise altitude. For comparison purposes, the energy content of the fuel of the baseline aircraft shall be 43.5 MJ/kg.	Test
	The CEPT system shall flight test	\$3.1	The SCEPTOR Sizing and Performance design approach shall enable a negative glide slope with the high-lift motors running at a speed between [VSO + 5 KCAS] and VSOhl at altitudes from sea level to 5000 feet.	Analysis
	the use of a S3.2 The SCEPTORS Sizing and Performance value for cruise shall be evaluated at Distributed Electric S3.3 The SCEPTOR Sizing and Performance approach for high-lift propeller design speed of no more than 140 m/s when operating at maximum power at VSOP Propulsion (DEP) The SCEPTOR Sizing and Performance shall provide lift augmentation for low	\$3.2	The SCEPTORS Sizing and Performance value for cruise shall be evaluated at 150 KTAS, 8000 ft MSL.	Inspection
3		The SCEPTOR Sizing and Performance approach for high-lift propeller design shall consider a tip speed of no more than 140 m/s when operating at maximum power at VSOhl at sea level.	Analysis	
		\$3.4	The SCEPTOR Sizing and Performance shall provide lift augmentation for lower-speed operations such that VSOhl < VSO, using high-lift motors and propellers distributed along the leading edge of the wing but not including the wingtips.	Analysis

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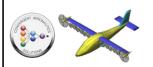
Requirements (2)



System Req No.	System Requirement Description	Subsystem Req No.	Subsystem Requirement Description	Verif. Method
	The CEPT system	\$3.5	The SCEPTOR Sizing and Performance shall provide the primary means of thrust generation on the ground and in flight, using cruise motors and propellers located near the wingtips.	Inspection
3	shall flight test the use of a Distributed Electric	\$3.6	The SCEPTOR Sizing and Performance shall have cruise propellers with a pitch setting that allows for reverse thrust generation without significant stalling of the blades over an airspeed range of [VS0hl - 5 KCAS] and [VS0 + 5 KCAS] and over a propeller speed range of 1700 to 2700 RPM.	Test
	Propulsion (DEP) concept.	\$3.7	The SCEPTOR Sizing and Performance shall have cruise motors and propeller governors that are able to control and maintain reverse thrust settings of the cruise propeller over an airspeed range of [VSOhl - 5 KCAS] and [VSO + 5 KCAS] and over a propeller speed range of 1700 to 2700 RPM.	Test
	The CEPT system shall provide	\$19.1	The SCEPTOR Sizing and Performance shall ensure the cruise motor and propeller shall accept a commercially available, electrically-actuated constant speed hub.	Inspection
19	volume for the electrical power system components.	\$19.2	The SCEPTOR Sizing and Performance shall ensure pylons and nacelles enable sufficient volume for wiring, instrumentation, motors, speed controllers, structural connections, and other associated hardware, including additional volume for adequate access.	Analysis
20	The CEPT system shall provide a mounting interface for the Cruise Motors.	\$20.1	The SCEPTOR Sizing and Performance shall place the cruise motors within nacelles located at the wingtips.	Inspection

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Performance & Sizing IPT 7



Requirements (3)



System Req No.	System Requirement Description	Subsystem Req No.	Subsystem Requirement Description	Verif. Method
21	The CEPT system shall provide a mounting interface for the DEP Motors.	S21.1	The SCEPTOR Sizing and Performance shall place high-lift motors within nacelles on pylons that extend below the wing.	Inspection
22	The CEPT system shall provide a wing to fuselage mechanical mounting interface compatible with the GA aircraft.	S22.1	The SCEPTOR Sizing and Performance shall place wing root of the new wing within the same footprint of the wing root of the baseline demonstrator.	Inspection

SCEPTOR PDR Nov. 12-13 2015 Performance & Sizing IPT 8

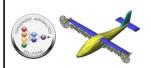


Requirements (4)



System Req No.	System Requirement Description	Subsystem Req No.	Subsystem Requirement Description	Verif. Method
	The CEPT system	S25.1	The SCEPTOR Sizing and Performance shall enable the demonstrator to land on a flat surface with at least a 10-degree bank with the landing gear extended.	Analysis
25	shall be capable of gliding to a safe landing on	\$25.2	The SCEPTOR Sizing and Performance shall have a minimum power-off rate of descent that is no more than 2.5 times the power-off rate of descent of the baseline aircraft at its published final approach speed.	Analysis
25	an approved surface in the event of total power loss.	\$25.3	The SCEPTOR Sizing and Performance shall operate at speeds of no less than 5 KCAS over the power-off stall speed of the current aircraft configuration when operating at less than 1,500 ft AGL, other than for takeoff or landing.	Test
		\$25.4	The SCEPTOR Sizing and Performance shall begin approach-to-landing segment an airspeed no less than [VSO + 5 KCAS].	Test
27	The CEPT system shall be capable of recovering from a failure in the cruise motors.	S27.1	The SCEPTOR Sizing and Performance takeoff and initial climb profile, when using only the cruise motors, will be conducted at speeds and power settings that enable immediate (that is, without consideration of deceleration effects due to thrust and drag imbalance) trimming of pitch, roll, and yaw forces from the primary flight controls in the event of failure of a single cruise motor, if possible. If a portion of the takeoff envelope results in an inability to immediately trim asymmetric forces due to engine failure, the takeoff and initial climb profile will select power settings that minimize the integral of the largest net moment imbalance over the total time of the net imbalance.	Analysis

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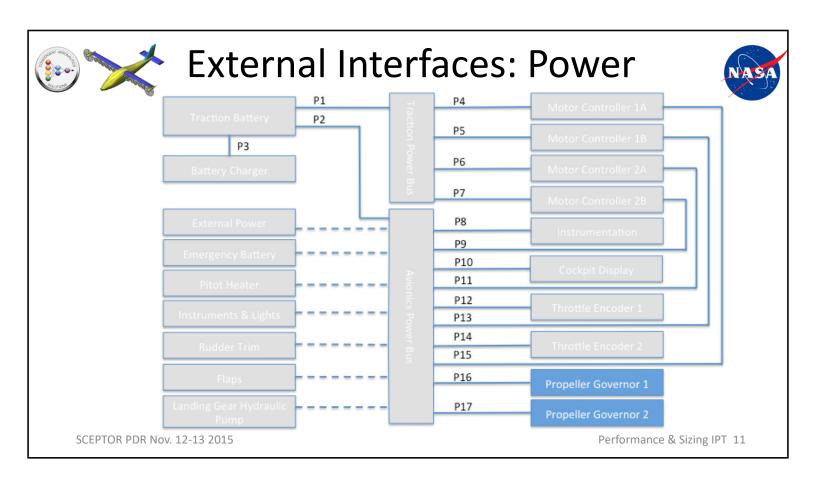


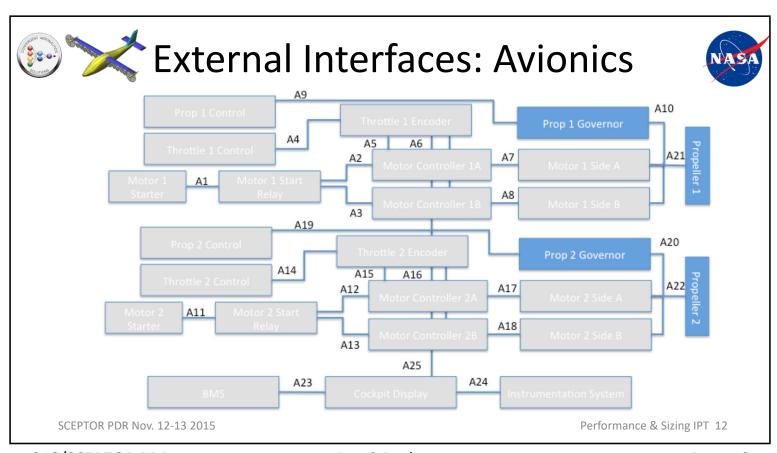
Requirements (5)



Syst Re No	q Requirement	Subsystem Req No.	Subsystem Requirement Description	Verif. Method
	The CEPT system shall operate	S30.1	Unless otherwise specified, the SCEPTOR Sizing and Performance values shall be established in still air using the 1976 US Standard Atmosphere.	Analysis
	within the flight envelope defined	S30.2	When specified as "Armstrong Hot Day," the SCEPTOR Performance values shall use the atmosphere established in S30.1, but with the temperature adjusted by +22 deg C.	Analysis
30	in Figure 1 and at the flight	\$30.3	The SCEPTOR Sizing and Performance approach shall consider cruise motors that output a maximum continuous shaft power of 60kW at 2250RPM throughout the CEPT flight envelope.	Test
	condition required to achieve the test objective.	\$30.4	The SCEPTOR Sizing and Performance values for the cooling system for the cruise and high-lift motors and controllers shall be able to operate at maximum continuous power throughout the relevant areas of the flight envelope during Armstrong Hot Day conditions.	Test

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SCEPTOR

Preliminary Hazard Summary IPT – Performance & Sizing



Preliminary Hazard

CEPT - PH13 Loss of Thrust During Takeoff

CEPT - PH15 Propeller Separation

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Performance & Sizing IPT 13



SCEPTOR

Preliminary Hazards
IPT - Performance & Sizing



Hazardous Act or Condition		Causes	Effects		Mitigations
CEPT- PH13 Loss of Thrust During Takeoff (Phase III)	C.	system Failure in electric motor Failure of motor controller Failure in propeller	 thrust (if failure affects both propulsors)	1. 2. 3. 4. 5. 6. 7.	provide partial takeoff power in event of single fault (A, B, C) Design review (A, B, C) Use COTS propellers/governors with an FAA type certificate (D, E

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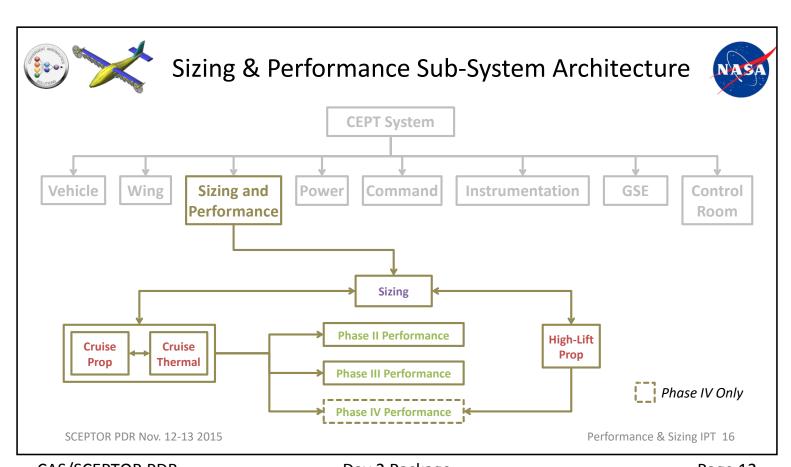


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Preliminary Hazards IPT – Performance & Sizing



Propeller B. Defects in composite/wood/metal/fasteners Separation C. Fatigue/End of Life D. Improper installation on attachment hardware E. Propeller over-speed F. FOD contact G. Excessive vibration H. Flutter I. Unbalanced prop J. Variable pitch/constant speed system failure K. Excessive aero loading L. Spinner failure M. Hub failure M. Ground strike D. Improper installation on attachment hardware E. Propeller over-speed F. FOD contact G. Excessive vibration F. Structural Failure of Failu	Hazardous Act or Condition	Causes	Effects	Mitigations
(A, B, D, G, H, I, J, L, M)	Propeller	B. Defects in composite/wood/metal/fasteners C. Fatigue/End of Life D. Improper installation on attachment hardware E. Propeller over-speed F. FOD contact G. Excessive vibration H. Flutter I. Unbalanced prop J. Variable pitch/constant speed system failure K. Excessive aero loading L. Spinner failure M. Hub failure N. Ground strike O. Bird strike P. Inadequate design (new motor/propeller	thrust Asymmetric thrust Loss of aircraft control Structural failure of nacelle/motor mount Damage or loss of aircraft Loss of aircraft Damage to ground assets Injury or death	engine run-up and taxi (A, B) 3. Monitor prop RPM (E, J) 4. Perform regular maintenance/overhaul (C) 5. Adhere to SCEPTOR operational placards and procedures (D, F, N, O) 6. Implement emergency motor power shut-down (E, G, H, I) 7. Motor controller design to limit RPM (E) 8. Fabricate propellers with high factor of safety and perform over-speed testing (A, B, E) 9. Use COTS components when available with substantiated safety margins (A, B) 10. Control room monitoring of vehicle dynamics (G, H, I)





Initial Sizing Requirements



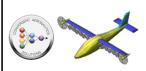
- What if takeoff and landing no longer sized your wing?
 - "Cruise-sized" wing needs to take minimum energy per unit distance
- Ran quick speed & range sensitivity
 - Tecnam fuselage not designed for high speed – shrinking wing has diminishing returns at higher speeds
 - Pointed to cruise speed goal of 150 KTAS at 8000 feet, 3000 lbf gross weight

Threshold (3.5x): 754 W-hrs/nm

Goal (5x): 528 W-hrs/nm

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Wingtip Cruise Propeller Design and Analysis

ISOLATED SYSTEM

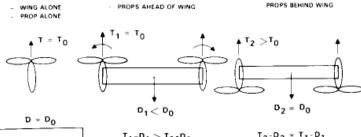


CASE II

- Propellers that operate in presence of wingtip vortex exhibit increased aerodynamic and/or propulsive efficiency if spun in opposite direction of tip vortex
- Benefit depends on placement with respect to wingtip¹
 - Tractor (in front of wingtip) largely results in induced drag reduction; pusher (behind wingtip) largely results in increased propulsive efficiency
 - This is just a bookkeeping exercise: for constant spanloading and constant input power, excess thrust for either configuration is conserved

CONSTANT SPANLOAD DISTRIBUTION CONSTANT POWER INPUT

CASE I



stant input $\tau_1 - \sigma_1 > \tau_0 - \sigma_0$ $\tau_2 - \sigma_2 = \tau_1 - \sigma_0$

1: L. Miranda, J. Brennan, "Aerodynamic Effects of Wingtip-Mounted Propellers and Turbines," AIAA-86-1802, 1986.

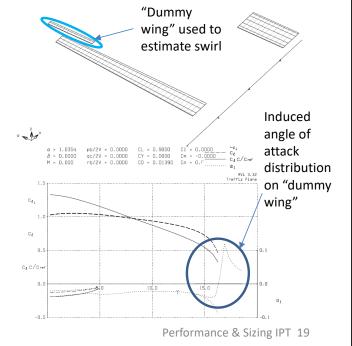
SCEPTOR PDR Nov. 12-13 2015 Performance & Sizing IPT 18



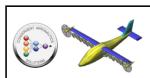
Wingtip Cruise Propeller Analysis Approach



- Needed fast, reasonably accurate method of estimating tip prop effect
- Used vortex lattice analysis on wing (AVL¹) to estimate swirl from wingtip vortex, feed into blade element momentum analysis (XROTOR²) to estimate propulsive efficiency
 - Rotational average of angle of attack distribution on "dummy wing" behind wingtip trailing edge (no wake, not included in wing/tail force calculations) used to estimate swirl from wingtip vortex



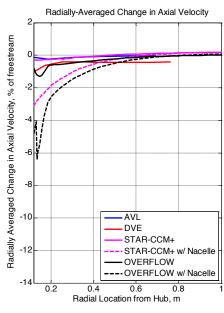
1: http://web.mit.edu/drela/Public/web/avl/ 2: http://web.mit.edu/drela/Public/web/xrotor/

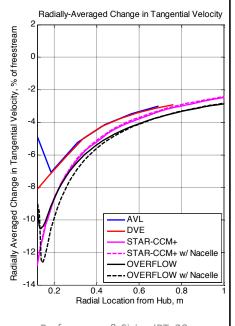


Isolated Wingtip Swirl Comparison



- Needed to check if wingtip swirl estimates from AVL adequately captured radiallyaveraged velocity
- CFD runs seem to indicate that AVL and Distributed Vorticity Element (DVE) swirl is conservative
 - These are potential codes and cannot capture viscous effects





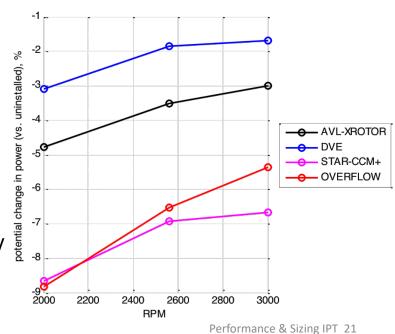
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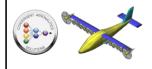
Installed Trends/Effects



- Desire to have wingtip tractor configuration due to acoustic, blade loading, aeroelastic effects (among others)
- Compared pusher (AVL-XROTOR) to tractor DVE and CFD results
- Chart on right shows effective decrease in power required if both efficiency and induced drag are bookkept as efficiency
 - Design method of choice (AVL-XROTOR) appears conservative vs. savings from CFD methods



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Wing & Cruise Propeller Design Exploration



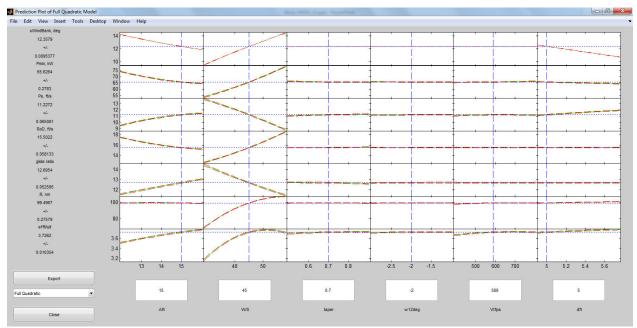
- Developed a fast wing tradespace exploration tool in MATLAB that is capable of investigating tens of thousands of different designs
- Ran through several iterations, discussed results with other IPTs in "open loop" fashion
 - In particular, Wing IPT input (aeroelastics, structures, airfoil design) would push back on aspect ratio, sweep, etc.
- Not design optimization, but "eyeballing" tradespace for inflection points
 - Main metrics: efficiency multiplier, rate of climb, range parameter, L/D
 - "Soft" constraints: max crosswind bank angle (limited by large tip prop diameter/high span), minimum sink rate (landing gear/safety for power-off)
- Largely optimistic aero (laminar-to-turbulent transition, small interference factors), but conducted with and without D/g margin of 0.5 to see if design wanted to go in different direction with added drag

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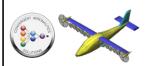
"Cruise-Sized" Wing Tradespace 🐼





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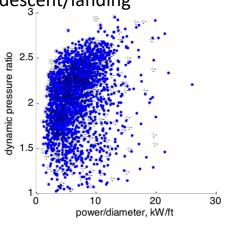
Performance & Sizing IPT 23

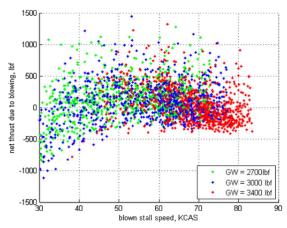


High-Lift Propeller Design



- Design of "high-lift" propellers requires different design approach
 - Instead of maximum thrust per unit input power, need maximum velocity jump per unit input power across entire wing
 - Thrust is a by-product you don't want to accelerate during descent/landing





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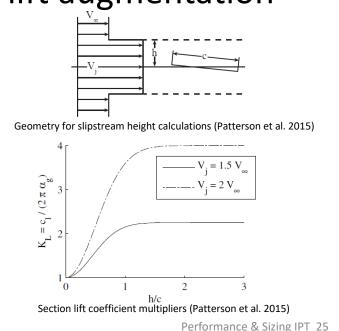
Effect of slipstream height-to-chord ratio on blown lift augmentation

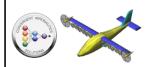


Sources from the 1970s
 (Ting et al.) showed that the dynamic pressure effect was reduced if the slipstream height was below a critical ratio of the chord length

 But... HEIST results and CFD don't seem to show this full effect (early results show that it's about 2x too

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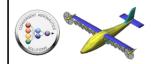
Effect of (modified) h/c on High Lift Props



- Current requirements targeting 58 KCAS stall speed, designed to 55 KCAS for margin (~10% lift margin)
- For a given wing, h/c gives a lower effective limit on number of high lift props
- Without h/c effect, BEM codes show that more props is always better

With ½ h/c effect With no h/c effect 200 200 otal Power (kW) 4000 4000 3000 100 100 6 8 10 12 14 16 6 8 10 12 14 16 Number of Props Number of Props Number of Props Number of Props 30 orque/prop (N-m) Power/prop (kW) Power/prop (kW) Number of Props Number of Props Number of Props Michael Patterson (NASA LaRC) Performance & Sizing IPT 26

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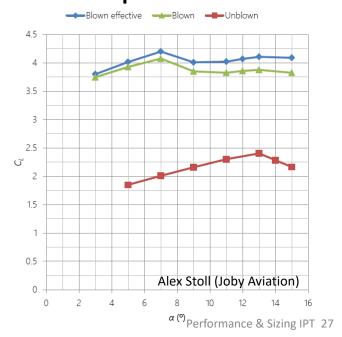


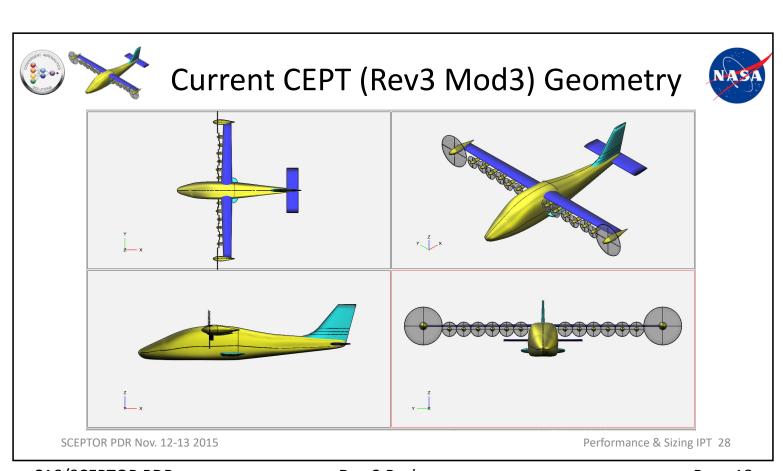
High-Lift Performance of Latest Wing/High Lift Propellers

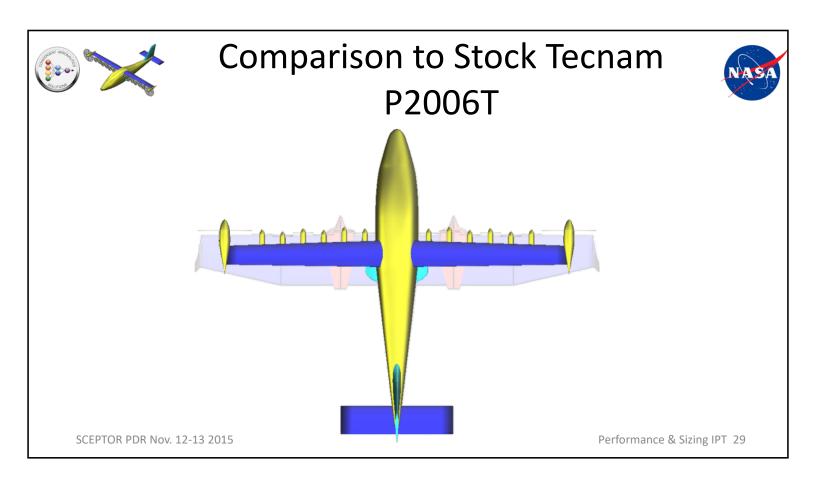


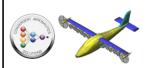
- Latest wing requires a C_{Lmax} of 4.0 at 58 KCAS, 4.4 at 55 KCAS
- Initial CFD estimates show that we can meet our highlift goals with a relatively simple flap system and DEP at 58 KCAS
- More validation ongoing, including development of folding props

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Technical Performance Measures



- V-speeds in for Phase II, III, and IV
 - Vr, Vx, Vy, Vbg, Vmc, Vmcg, Vapp, Vfe, Vs0, Vs1, Vs0hl, Vs1hl, VA, VNE, (V1, V2)
- Performance maps (vs. h, V, at 1g & MTOW)
 - Rate of climb (Ps)
 - Angle of climb
 - L/D power on, off (latter for glide performance)
 - Power required
 - Efficiency multiplier*

- Cruise & high lift propellers
 - Max. continuous power, torque
 - Torque, RPM for takeoff, climb, cruise, descent conditions
 - Rotational & helical tip speeds
- Cooling effectiveness
 - Cruise motor, controller temperature at relevant conditions

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Notable Dimensions and Characteristics



Wing

- Span: 9.639m (31.62ft)

Root chord: 0.756m (2.48ft)

Tip chord: 0.529m (1.74ft)

LE sweep: 1.887 deg

Sweep @ 0.7c: 0 deg

Airfoil: gnew5bp93 (15%)

- Area: 6.194m² (66.67ft²⁾

Aspect ratio: 15 Washout: 2 deg

Root incidence: 2 deg

- Wing loading: 2153 N/m² (45.0

lbf/ft²) (@3000 lbf)

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Cruise Props

Number: 2

Diameter: 1.524m (5ft)

Blades: 3

Airfoil: MH117

 Power @ 3000 lbf, 150KTAS, 8000ft: 43kW @ 2250 RPM

High Lift Props

Number: 12

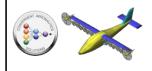
Diameter: 0.576m (1.89ft)

Blades: 5

Airfoil: MH114

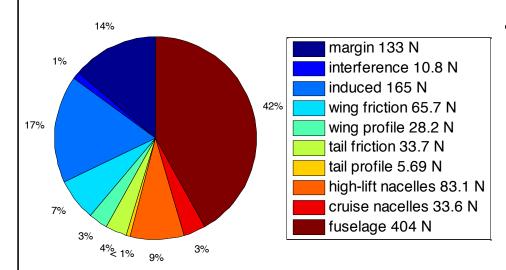
Power @ 55KTAS, SL: 14.4kW

@ 4548 RPM Performance & Sizing IPT 31



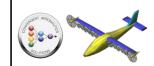
Drag Buildup at 150KTAS, 8000 ft





- Total drag of about 962N
 - This figure **INCLUDES** estimated tip prop savings of approximately 57N, or about 5% of total drag

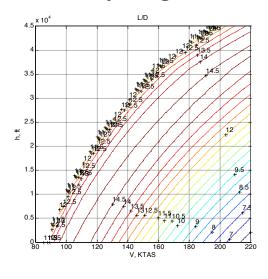
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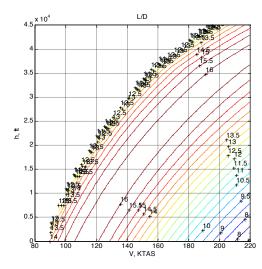
L/D – Power Off



With 0.5 D/q margin

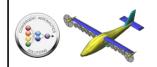


No D/q margin added



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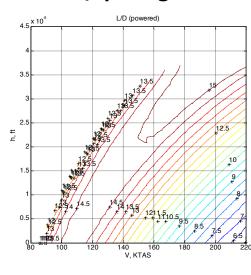
Performance & Sizing IPT 33



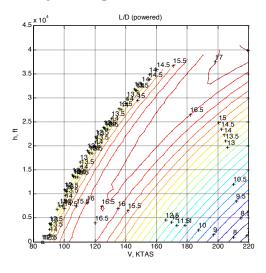
L/D – Power On (Tip Effect)



With 0.5 D/q margin



No D/q margin added



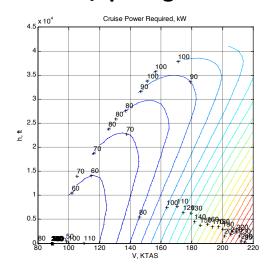
SCEPTOR PDR Nov. 12-13 2015



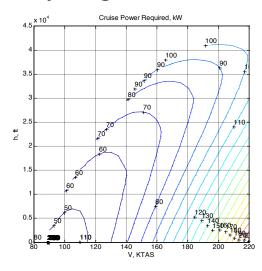
Power Required for Level Flight



With 0.5 D/q margin

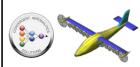


No D/q margin added



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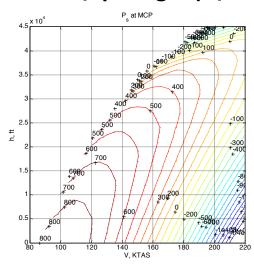
Performance & Sizing IPT 35



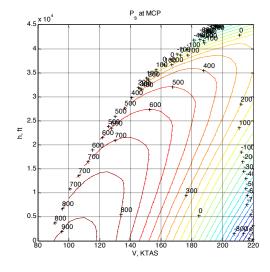
Rate of Climb at Maximum Continuous Power (Cruise Motors Only)



With 0.5 D/q margin (ft/min)



No D/q margin added (ft/min)



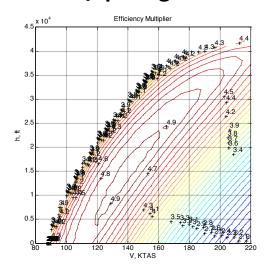
SCEPTOR PDR Nov. 12-13 2015



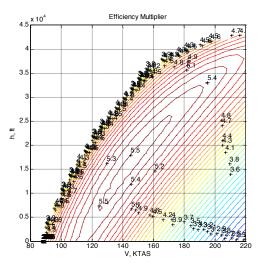
Efficiency Multiplier vs. Tecnam at Max Cruise 🚾



With 0.5 D/q margin



No D/q margin added



SCEPTOR PDR Nov. 12-13 2015

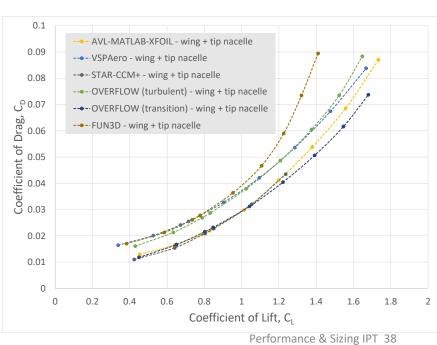
Performance & Sizing IPT 37



>>> Issues & Resolutions to Date (1)

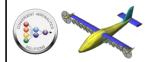


- Conceptual methods for design may be associated with significant uncertainty
 need verification approach
 - Due to lack of experimental data, considering two independent higher-order methods as validation approach
 - Developed build-up test matrix to test assumptions; plan to document in AIAA paper



SCEPTOR PDR Nov. 12-13 2015

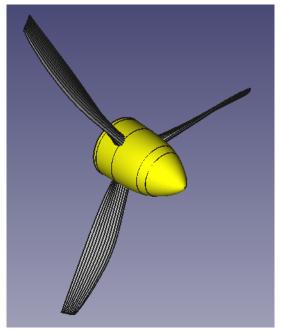
Day 2 Package Page 23



Issues & Resolutions to Date (2)

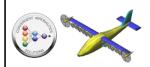


- Phase II/III cruise propeller mismatch
 - Identified Type Certified COTS propeller that yields very similar efficiencies to custom cruise propeller
 - Need to evaluate performance in Phase II, III, an IV configurations



Performance & Sizing IPT 39

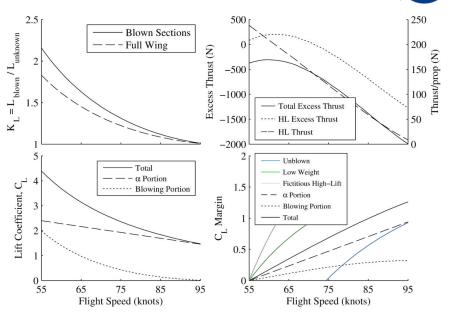
SCEPTOR PDR Nov. 12-13 2015



Issues & Resolutions to Date (3)



- Blowing from highlift props may result in too much thrust for descent
 - Added windmilling requirements to cruise motors
 - Evaluated approach speed/gust margin
 - May be able to set Phase IV to partialspan blowing with current design



SCEPTOR PDR Nov. 12-13 2015 Performance & Sizing IPT 40

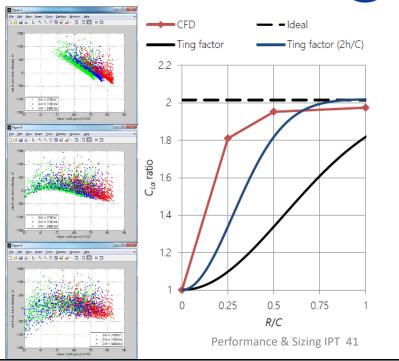


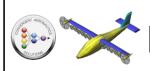
Issues & Resolutions to Date (4)



- Amount of blowing needed highly uncertain due to h/c effect, angle of installation, height of nacelles
 - HEIST data comparison vs. design-order tools
 - Pylon installation for highlift motors
 - Upcoming prop height/angle study

SCEPTOR PDR Nov. 12-13 2015



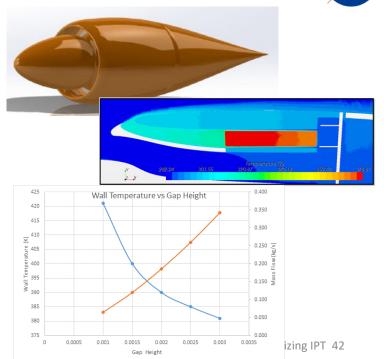


>> Issues & Resolutions to Date (5)



- Air cooling for cruise motor during Armstrong hot day operation
 - Developed annular inlet design that is robust to flight conditions
 - Centrifugal fan to increase airflow, along with updraft cooling
 - Quasi-1-D analysis coupled with higher-order approaches for cooling design

SCEPTOR PDR Nov. 12-13 2015





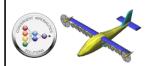
Path to CDR



- Phase I data reduction to refine key TPM: multiplier over energy used per unit distance
- Cooling analysis & design for cruise motors
- Wing/nacelle interaction drag reduction (cruise and highlift)
- High-lift propellers: HEIST validation, height & angle study
- Folding prop design for Phase IV, performance analysis

SCEPTOR PDR Nov. 12-13 2015

Performance & Sizing IPT 43



Exit Criteria



Subsystem Level Exit Criteria	Evidence
Subsystem level requirements identified and flow to system parents	Slides 6-10
Subsystem level designs and analysis exist and are consistent with corresponding requirements	Slides 28-37
Subsystem level interfaces identified and consistent with design maturity	Slides 11-12
Project risks identified and mitigation strategies defined	N/A
Test & Verification approach is adequate	Slides 38-42
Preliminary hazards adequately addressed and considered in the preliminary design	Slides 13-15

SCEPTOR PDR Nov. 12-13 2015





Wing IPT

Jeff Viken

Jeffrey.K.Viken@nasa.gov

757-864-2875



Entry Criteria



Subsystem Level Entry Criteria	Evidence
Technical Performance Metrics (TPMs)	17, 26-32, 43, 51-55, 71
Preliminary Subsystem Requirements and/or Specifications	5-7
Draft Interface Control Documents	12
Design and Analysis	18-25, 33-91
Drawing Tree	15
Test and Verification Planning	93

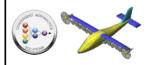


Schedule to CDR



Removed

SCEPTOR PDR Nov. 12-13 2015 Wing IPT 3



Document Status



Doc No.	Doc Type	Document Title	Status
CEPT-REQ-002	Requirements	Wing Subsystems Requirements	In-Development
CEPT-ICD-004	ICD	Wing Interface Control Document	In-Development
CEPT_ANLYS-XXX	Analysis	Wng Structural Analysis	In-Development
CEPT_ANLYS-XXX	Analysis	Wing Aeroelastic Analysis	In-Development
CEPT_ANLYS-XXX	Analysis	Wing Performance Analysis	In-Development



Requirements (1/3)



Req.	Statement	Subsystem Req. #	Subsystem Requirement Definition	Verification Method
3	The CEPT system shall flight test the use of a Distributed Electric Propulsion (DEP) concept.	W3.1	The wing shall be designed to include DEP motors and the power system accounting for the DEP lift benefits at landing.	Analysis
		W5.1	The wing shall meet the requirements of Armstrong Aircraft Structural Safety of Flight Guidelines G-7123.1-001.	Analysis
5	The CEPT system shall be inhabited.	W5.2	The wing shall be structurally tested to the requirements of Armstrong Aircraft Structural Safety of Flight Guidelines G-7123.1-001.	Test
	_	W5.3	The wing shall be designed with a mechanical flight control system.	Inspection
15	The CEPT system shall be controllable and monitored by EGSE during integration and checkout activities.	W15.1	The wing shall provide access and monitoring of the power and control systems by EGSE for the both the Cruise motors and DEP motors during integration and checkout activies.	Inspection
18	The CEPT system shall be a mechanical flight control system.	W18.1	The wing shall be designed with a mechanical flight control system that interfaces with the Tecnam fuselage control system.	Inspection
19	The CEPT system shall provide volume for the electrical power system components.	W19.1	The internal wing volume shall accommodate all volume requirements for the Cruise motors, DEP motors, and instrumentation systems.	Inspection

SCEPTOR PDR Nov. 12-13 2015 Wing IPT 5



Requirements (2/3)



Req. No.	Statement	Subsystem Req. #	Subsystem Requirement Definition	Verification Method
20	The CEPT system shall provide a	W20.1	Thie wing shall provide a mounting structure for the Cruise Motors that interfaces to the wing primary structure.	Analysis
20	mounting interface for the Cruise Motors.	W20.2	The wing shall provide aerodynamic nacelles for the Cruise Motors.	Analysis
The CEPT system shall provide a	W21.1	Thie wing shall provide a mounting structure for the DEP Motors that interfaces to the wing primary structure	Analysis	
	mounting interface for the DEP Motors.	W21.2	The wing shall provide aerodynamic nacelles for the DEP Motors	Analysis
22	The CEPT system shall provide a wing to fuselage mechanical mounting interface	W22.1	The wing shall provide an interface to mount to the Tecnam fuselage.	Analysis
22	compatible with the GA aircraft.	W22.2	Additional structure shall be designed and installed, as needed, that interfaces the SCEPTOR wing to the Tecnam fuselage.	Analysis
25	The CEPT system shall be capable of 25 gliding to a safe landing on an approved surface in the event of total power loss.	W25.1	The wing shall provide mechanical flight controls that do not require power to operate.	Inspection
25		W25.2	The flaps shall have the capbility to be extended by power available from the emergency power system.	Inspection



Requirements (3/3)



Req.	Statement	Subsystem Req. #	Subsystem Requirement Definition	Verification Method
26	The CEPT system shall be capable of recovering from a failure in the high lift motor system.	W26.1	The wing shall be designed such that any change in forces due to loss of the high-lift motor system will be controllable by the SCEPTOR aircraft.	Analysis
27	The CEPT system shall be capable of recovering from a failure in the cruise motors.	W27.1	The wing shall be designed such that any change in forces due to loss of the both motors of the Cruise motor system will be controllable by the SCEPTOR aircraft.	Analysis
30	The CEPT shall operate within the flight envelope defined in Figure 1 and at the flight condition required to achieve the test objective.	W30.1	The wing shall be designed to operate safely within the envelope defined in Figure 1 and at the flight condition required to achieve the test objective.	Analysis
22	The CEPT system shall validate all new primary and secondary structure contain	W32.1	The wing shall be designed to meet the requirements of Armstrong Aircraft Structural Safety of Flight Guidelines G-7123.1-001.	Analysis
1	sufficient structural margin for the applied loads.	W32.2	The wing shall be structurally tested to the requirements of Armstrong Aircraft Structural Safety of Flight Guidelines G-7123.1-001.	Test

SCEPTOR PDR Nov. 12-13 2015 Wing IPT 7



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Preliminary Hazard Summary

IPT - Wing



Preliminary Hazard

CEPT - PH2 Structural Failure of Wing (Phase III)

CEPT - PH7 Wing Control Surface System Failure (Phase III)

CEPT - PH12 Whirl Flutter (Phase II & III)

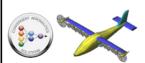


SCEPTOR

Preliminary Hazards IPT - Wing



Hazardous Act or Condition	Causes		Effects		Mitigations
CEPT- PH2	A. Composite		Loss of aircraft	1.	Installation procedure/inspection (L)
Structural	delamination		control	2.	Perform pre/post flight inspections (A, B, C, F, H, I, J, K, L)
Failure of Wing	B. Defects in composite	•	Damage or loss of	3.	Design review (B, D, E, G, L)
(Phase III)	material /		aircraft	4.	Analysis review (B, D, E, G)
	manufacturing	•	Damage to	5.	Adhere to POH, operational placards and SCEPTOR procedures
	C. FOD contact		ground assets		(D, E)
	D. Divergence/Flutter	•	Injury or death to	6.	Control room monitoring of vehicle dynamics (C, D, E, H, I, J, K)
	E. Excessive loading		personnel	7.	Wing designed to specified factor of safety with positive margins
	F. Bird strike				(D, E, G, H, I, J, K)
	G. Improper loads cases			8.	Coupon testing/documentation of composite material system (A, B
	H. Nacelle/wing interface			9.	Fabrication procedure (A, B, H, I, J, K)
	structural failure			10.	Quality control process (A, B, H, I, J, K, L)
	I. Fuselage/wing interface			11.	Wings loads test (A, B, L)
	structural failure			12.	Wing inspection (NDI) pre/post ground test (A, B)
	J. Control surface			13.	Aircraft GVT (D)
	attachment failure			14.	Taxi test (H, I, J, K, L)
	K. Failure of attach point			15.	Monitor BASH (F)
	hardware			16.	Chase aircraft (F, H, I, J, K, L)
	L. Improper installation				



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Preliminary Hazards IPT - Wing



		ir i - willig	
Hazardous Act or Condition	Causes	Effects	Mitigations
CEPT- PH7	A. Composite delamination	Loss of aircraft control	1. Adhere to POH, operational placards and SCEPTOR
Wing Control	B. Defects in composite	 Damage or loss of 	procedures (C, D, E)
Surface System	material / manufacturing	aircraft	2. Design review (C, D, E, F, G, H)
Failure (Phase III)	C. Excessive wing	 Damage to ground 	3. Analysis review (C, D, E, F, G, H)
	deflection/binding	assets	4. Control room monitoring of vehicle dynamics (C, D, E, G,
	D. Flutter	 Injury or death to 	H)
	E. Excessive aero loading	personnel	5. Control surface system designed to specified factor of
	F. Improper load cases		safety with positive margins (B, C, E, F, G, H)
	G. Failure of attachment point hardware		Coupon testing/documentation of composite material system (A, B, G)
	H. Flap actuation system		7. Aircraft GVT (A, B, C, D, F, G, H, I)
	failure		8. Taxi Test (C, D, G, H, I)
	I. Improper installation		9. Chase Aircraft (C, D, G, H)
	J. FOD intrusion		10. Wings loads test (A, B, C, E, F, G, H, I)
			11. Quality control process (A, B, G, H, I, J)
			12. Fabrication procedure (A, B, G, H, I)
			13. Installation procedure/inspection (I)
			14. Control surface inspection (NDI) pre/post ground test
SCEPTOR PDR Nov	v. 12-13 2015		(A, B, D, E, F, I) Wing IPT 10

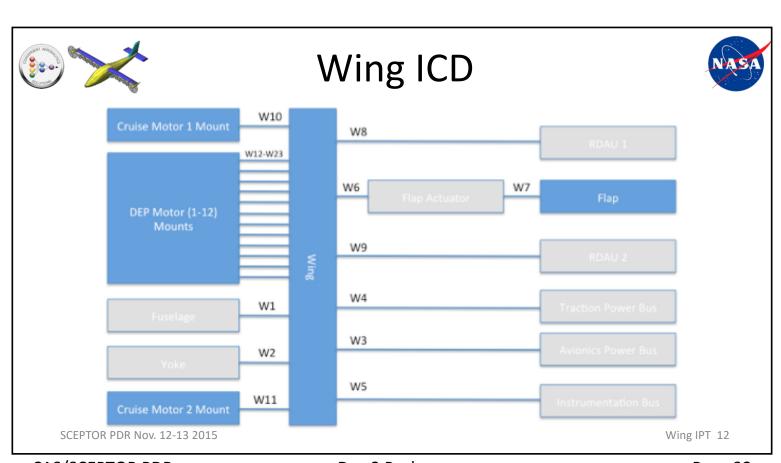


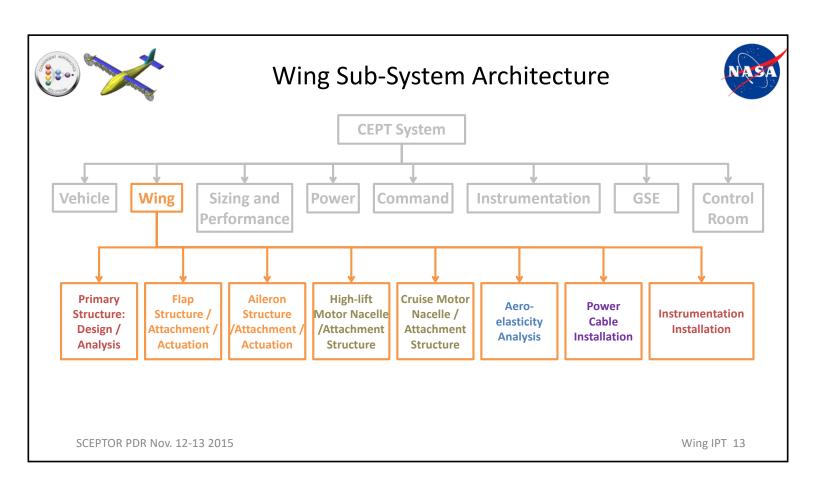
SCEPTOR

Preliminary Hazards IPT - Wing



Hazardous Act or Condition	Causes	Effects	Mitigations
CEPT- PH12 Whirl Flutter (Phase II & III)	A. Insufficient stiffness in pitch/yaw motion of any or all motors/nacelles B. Coupling between pitch/yaw modes of a nacelle C. Coupling between a nacelle and wing mode D. Rotor or prop imbalance E. Improper propeller blade design (mass distribution, twist distribution, blade stiffness) F. Defects in assembled component design G. Excessive pilot control inputs H. Defects in fabrication I. Defects in assembly J. FOD contact K. Propeller over-speed L. Failure of propeller governor M. Excessive aero loading N. Mechanical failure (Spinner/Hub) O. Ground strike P. Bird strike Q. Improper Installation	Loss of thrust Asymmetric thrust Damage or Loss of propeller Damage or Loss of motor Damage or loss of aircraft Damage to ground assets Injury or death to personnel	 Analysis review (including measured nacelle mode frequencies) (A, B, C, E, M) Design review (wing/nacelle/motor systems to not have interacting unstable modes) (A, B, C, E, M) Quality control process (D, F, H, I, Q) Installation procedure/inspection (D, F, H, I, Q) Aircraft GVT to include nacelle modes (A, B, C, F, H, I, Q) Control room monitoring of vehicle (dynamics and nacelle/motor dynamics) (A, B, C, D, E, F, I, K, L, M, N, Q) Large factor of safety applied to whirl flutter margin and propeller design, to include hub/spinner assembly (A, B, C, D, E, F, H, I, K, L, M, N, Q) Inspect prop/spinner pre/post flight (D, F, H, I, J, M, N, O, P, Q) Listen for abnormal sounds/vibration during engine run-up and taxi (A, B, C, D, E, F, H, I, M, N, Q) Monitor prop RPM (D, K, L, N) Perform regular maintenance/overhaul (D, F, H, I, N, Q) Adhere to POH, operational placards and SCEPTOR procedures (B, C,G, K, N) Perform motor/propeller over-speed testing utilizing flight configuration on test stand (A, B, D, E, F, H, I, K, L, M, N, Q) Chase Aircraft (B, C, J, N, P, Q) Taxi test (A, B, C, D, E, F, H, I, K, L, M, N, Q)







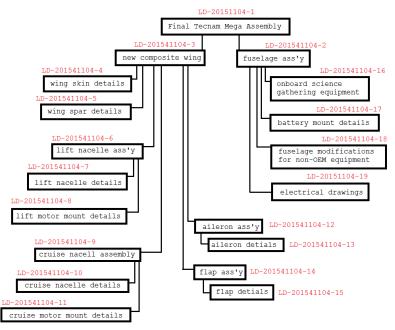


SYSTEM DETAILS



System Details: Configuration Management





- All drawings will be numbered according to Drawing Tree
- Follow established LaRC procedures for engineering/fabrication configuration control
- Will use follow appropriate standards of
 - LPR 7320.1 Engineering Drawing System
 - LPR 1740.4 Facility System Safety Analysis and Configuration Management
 - NASA-STD-0005 NASA Configuration Management Standard

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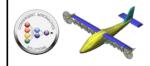




Wing IPT 15

SCEPTOR PDR CFD NASA LaRC

Karen Deere Sally Viken Melissa Carter



Technical Performance Metrics



- Airfoil
 - Cl (cruise)
 - Cd (cruise)
 - Cl_{max}
 - Alpha stall
 - Stall break
- Wing
 - Cruise
 - CL_{max}
 - CD
 - CM
 - Landing
 - Cl_{max} (unblown)
 - Cl_{max} (blowing)
 - CD
 - CM

Need cl (cruise) ~ 0.75 to meet sizing requirement

Need CL_{max} (blown) > 4.0 to meet stall requirement

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Wing IPT 17

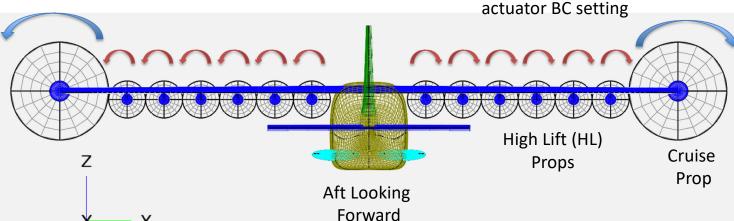


Prop Rotations, Pilot's View



For β =0 cases we grid ½ geometry and model full airplane with symmetry bc.

Clockwise Right Wing: Vt_ratio > 0 in





Flight

High Lift

- 55 KTAS
- h = 0 feet
- $T = 59 \, ^{\circ}F$
- -M = 0.083
- Re = 1,264,431

Cruise

- 150 KTAS
- h = 8000 feet
- $T = 30.5 \,^{\circ}F$
- -M = 0.233
- Re = 2,833,455

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Conditions

Propulsion (Actuator Disk BC)

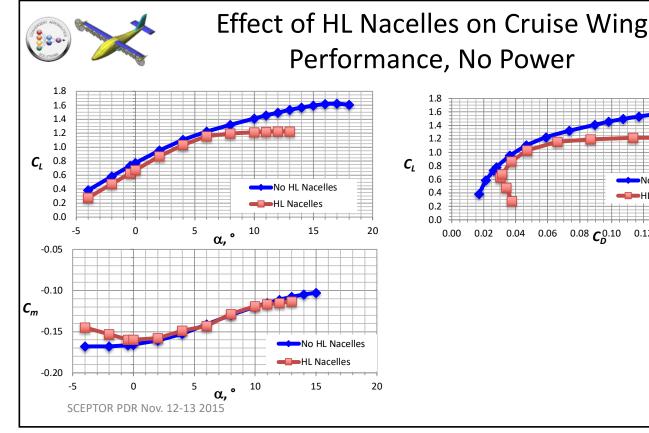
High Lift Props

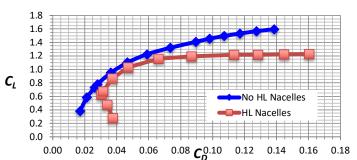
- 19.3 SHP/prop, 231.5 SHP
- Thrust=64.74 lb, Torque=22.27 ft-lb, 4548 RPM
- C_t=0.047893, C_g=0.017436, V_{t ratio}=4.8484

Cruise Props

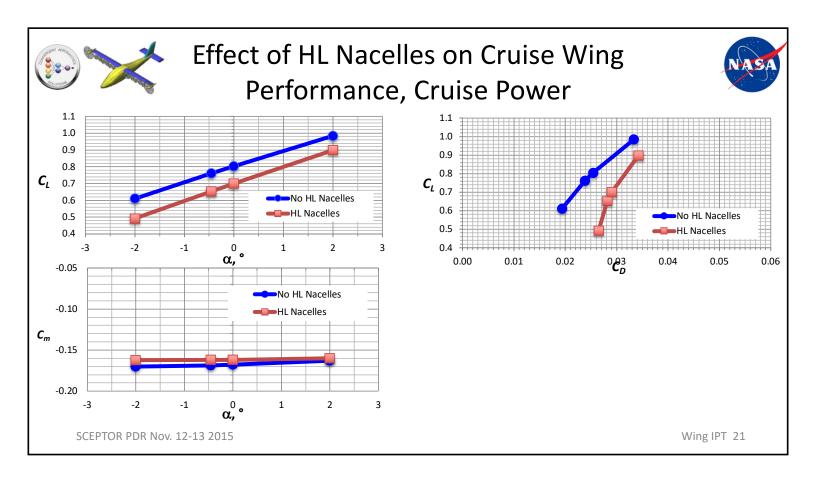
- α=-2°
- 123.86 SHP
- Thrust=122.75 lb, Torque=144.6 ft-lb, 2250 RPM
- $C_t = 0.009632$, $C_q = 0.004538$, $V_{t ratio} = 2.3267$
- $\alpha = -0.452^{\circ}$ 128.92 SHP
 - Thrust=127.69 lb, Torque=150.46 ft-lb, 2250 RPM
- C_t =0.010020, C_q =0.004723, $V_{t ratio}$ =2.3267
- 131.45 SHP
- Thrust=130.16 lb, Torque=153.41 ft-lb, 2250 RPM
- C_t =0.010214, C_q =0.004815, $V_{t ratio}$ =2.3267
- 147.88 SHP
- Thrust=145 lb, Torque=172.59 ft-lb, 2250 RPM
- $C_t = 0.011378$, $C_o = 0.005417$, $V_{t ratio} = 2.3267$

Wing IPT 19





Wing IPT 20

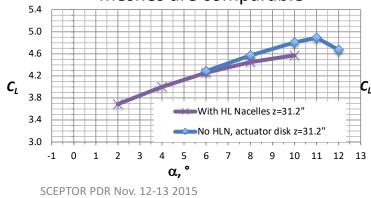


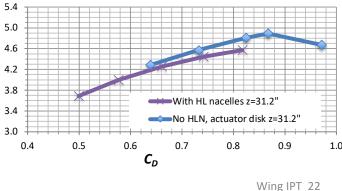


Effect of HL Nacelles on 30° Flap Wing Performance



- 30° Flap (back and down position) Wing, HL Power
- Solutions from coarse mesh (wick grids)
 - Used for initial data when fine grid wasn't available
 - Should show deltas well, between with and without HLN because the meshes are comparable



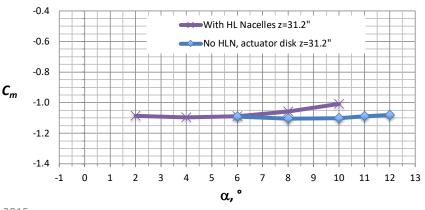




Effect of HL Nacelles on 30° Flap Wing Cm



30° Flap (back and down position) Wing, HL Power



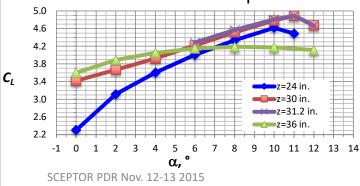
SCEPTOR PDR Nov. 12-13 2015 Wing IPT 23

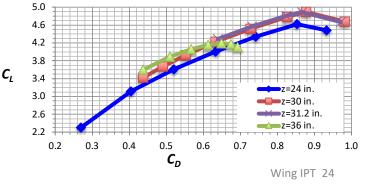
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Effect of HL prop placement on C_L and C_D



- 30° Flap (back and down position) Wing, HL Power, No HLN
- Solutions from coarse mesh (wick grids)
 - Used for initial data when fine grid wasn't available
 - Should show deltas well, between with and without HLN because the meshes are comparable



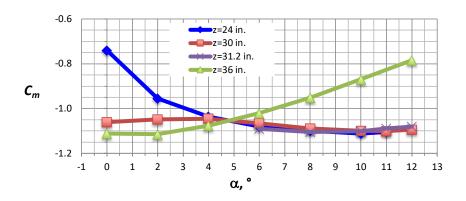




Effect of HL prop placement on C_m



 30° Flap (back and down position) Wing, HL Power but no HL nacelles



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SCEPTOR PDR
Composite Structures Design
Criteria
Verification, Validation and Testing
Process
NASA AFRC

Wesley Li



Design criteria



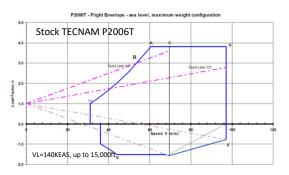
Structural Design Criteria

- Based on "Aircraft Structural Safety of Flight Guidelines (G-7123.1-001) and FAR Part 23.
- Max Gross weight and landing weight is 3,000 lb
- Maneuver limits Load Factors maximum and minimum load factors at are +3.8 G and –1.78 G. For asymmetric conditions, the maximum and minimum load factors at are +2.0 G and +0.5 G.
- The ultimate factor of safety for wing structure shall be 1.8.
- The ultimate factor of safety for secondary structure shall be 2.25.
- The ultimate factor of safety for thermal loads shall be 1.25 (Temperature Effects)
- Load cases includes ground, flight and gust.
- The items of mass within cabin that could injure an occupant shall design to crash loads requirement, FAR 23.561. The ultimate factor of safety for crash loads shall be 1.00.



- Temperature based on EAFB ambient NASA/TM-2008-215633 (table 3-7)
- -21 to 113 degrees F
- Fatigue design criteria (Flight testing hours / no. of landings)

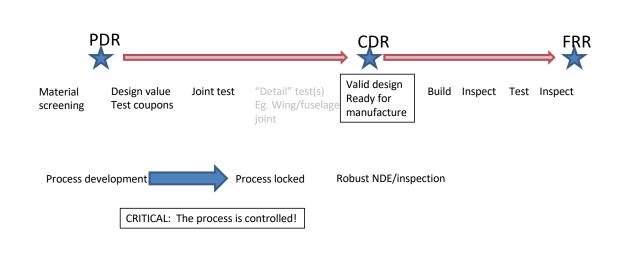
SCEPTOR PDR Nov. 12-13 2015 Wing IPT 27

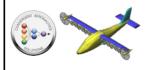




Composite life cycle







Composite Structures Verification and Validation (V&V) process



- Building-block approaches for testing and analysis will be used. MIL-HDBK-17-1F (2002)
- Composite material property, design allowable and composite processing will be based on the AGATE Database, http://www.niar.wichita.edu/agate/
- **Material Equivalency testing** will be used to help set benchmarks in chemical, physical, process, and mechanical properties, which are used with other quality checks for subsequent material and process control.
- Bonded joint implies statistical testing will be conducted to verify the local modeling approaches and strength of the bond process.
 - Material Design value Joint test "Detail" test(s) Valid design Ready for Test coupons Eg. Wing/fuselage Ready for Ready for Test Coupons

From: MIL-HDBK-17-1F (2002)

- Witness coupons will be available for testing if required.
- Component (wing) testing to verify and validate the wing structural integrity
- Contractors will provide their composite cure process, process specification, and process control for AFRC review.

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Material Equivalency Test Recommendations



- Composite material property, design allowable and composite processing will be based on the AGATE Database, http://www.niar.wichita.edu/agate/
- To verify Room Temperature Dry (RTD) condition.
- One (1) batch of material is the minimum required for this testing.
- Two separately processed panels are used in obtaining specimen for strength tests.
- Other Laminate design will be tested

No.	Test	Specimen (RTD)
1	0º (warp) Tensile Modulus, Strength and Poisson's Ratio	5
2	90º (fill) Tensile Modulus and Strength	5
3	0º (warp) Compressive Strength and Modulus	5
5	90º (fill) Compressive Strength and Modulus	5
6	In-Plane Shear Modulus and Strength	5
7	Short Beam Shear	5

Source: FAA Policy Memo on Equivalency testing.pdf, 2003



Bonded Joint Allowable Test Recommendations



- Composite material property, design allowable and composite processing will be based on the AGATE Database, http://www.niar.wichita.edu/agate/
- Bonded joint allowable testing will be conducted to verify the strength of the bond process.
- Depend on the types of bonded joints going to design on the wing i.e., solid laminate angle joint and sandwich-sandwich joint (rib-to-skin, sin stiffener interaction, bond thickness)
- Enough unique batches of materials, independent bonding process trials and test repetitions are REQUIRED to ensure a representative population for reliable benchmarks.
- Two batches of material are the minimum required for this testing.
- Five separately processed joint coupon are used for tests.

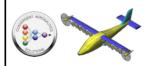
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Ground Testing



- AFRC Flight Loads Lab (FLL) process will be followed
- AFRC Aircraft Structural Safety of Flight Guidelines, G-7123.1-001.
- Qualification / acceptance test (Wing only)
 - Objective: to validate the wing structural integrity
 - Test up to 120% of DLL
 - Critical load conditions: Up-bending, down-bending and worst torsion
 - Pre and post test inspection will be performed, i.e. Visual, tap test, NDI
- Flight test strain gages calibration test (Integrated Wing)
 - Objective: to calibrate the flight test strain gages
 - Test up to approx. 30% of DLL
 - Ground vibration test (Integrated Wing and vehicle in flight configuration)
 - Objective: to identify the structural modes and the associated mode shapes as well as frequency and damping values.
 - The modal data will be used for the correlation and verification (and modification if necessary) of the structural dynamic FEM used in the flutter analysis.





Structural Design:

Wing
Wing-Tip Motor
High-Lift Motor
Wing/Fuselage Attachment Structure

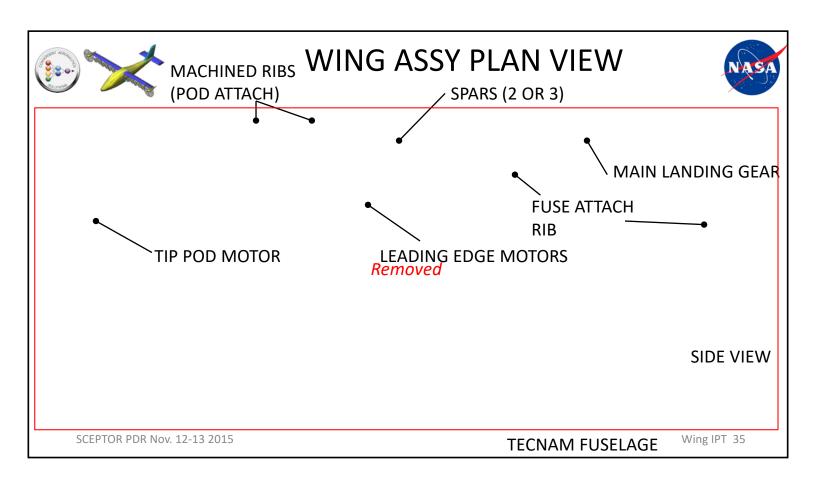
NASA LaRC Jim Moore

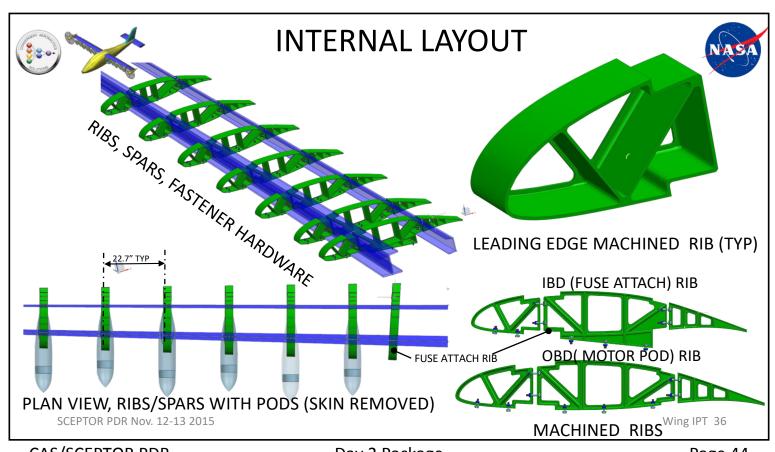


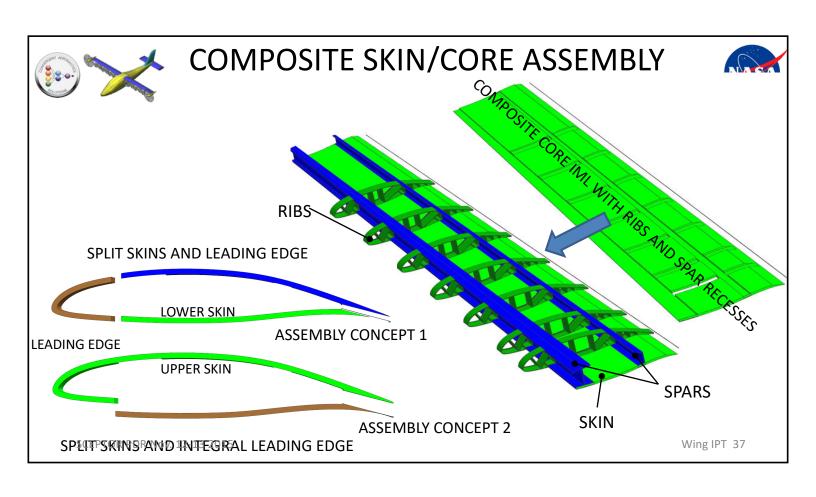
WING LAYOUT, WING ATTACHMENT

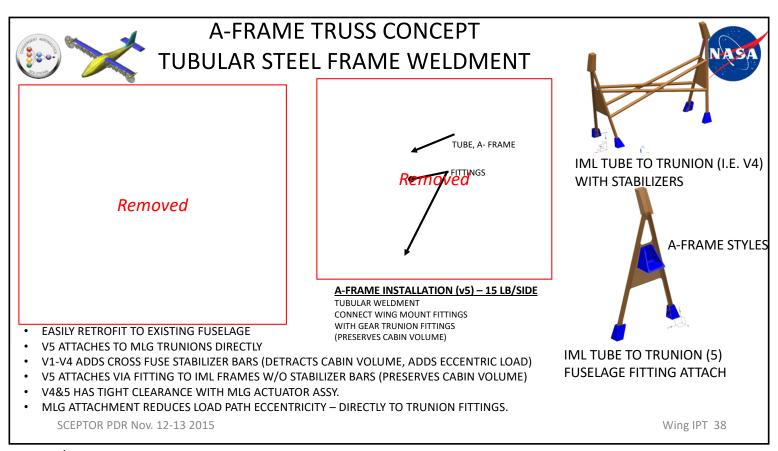


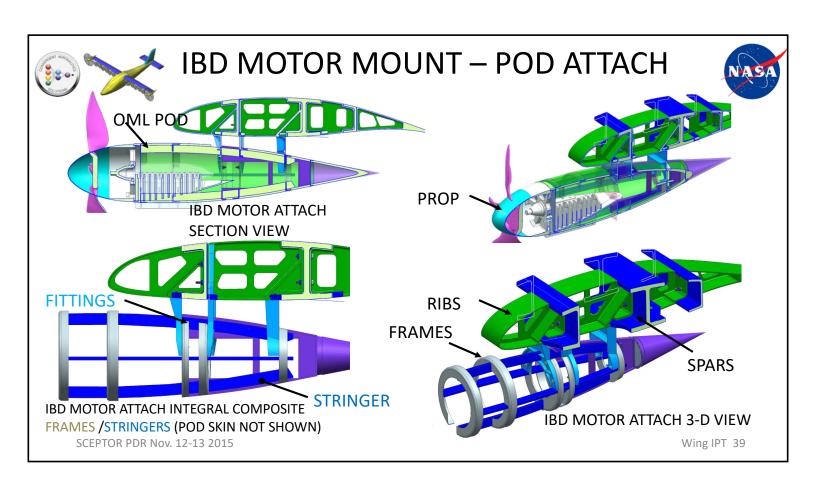
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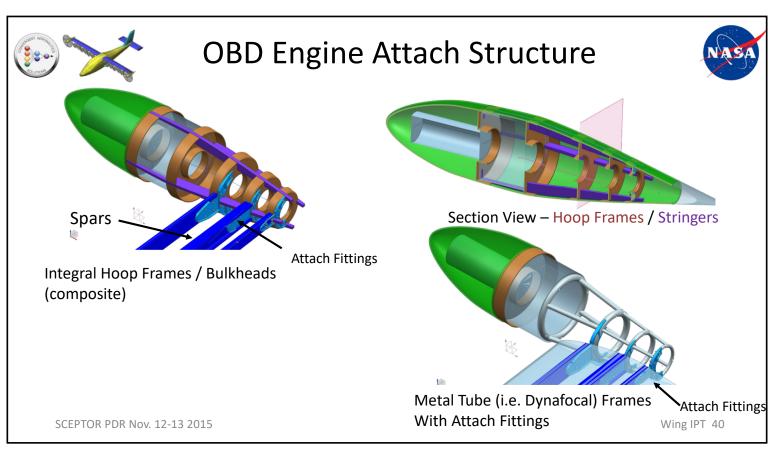


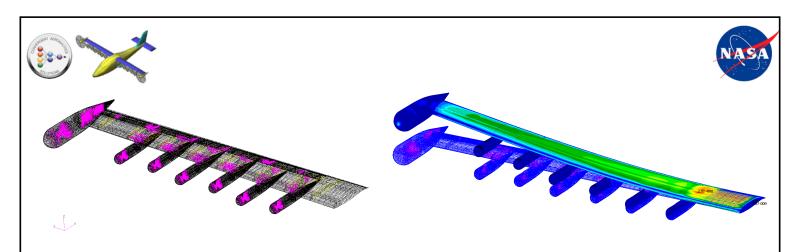












SCEPTOR PDR Wing Structural Analysis

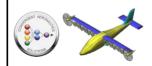
Steve Cutright
NASA Langley Research Center
757-864-8118



Structural Analysis Overview



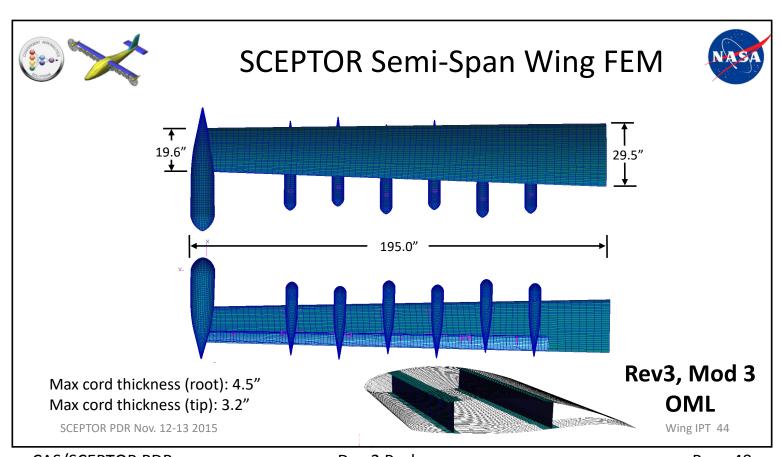
- Structural analysis model created from semi-span wing model (two spars, flap recessed)
 - Uses Rev3Mode3 DOE9 Beta Finite Element Model (FEM), 7 engine pods
- Wing structure fabricated from composite materials
 - Total wing weight of 288.7 lbs
 - Includes electric motors as lumped masses
- Secondary structure not included in detail as designs are still maturing. Analysis does not include:
 - Flap/aileron actuation structure
 - Wiring and attachments
- Preliminary analyses indicate positive margins on primary structure for driving load cases

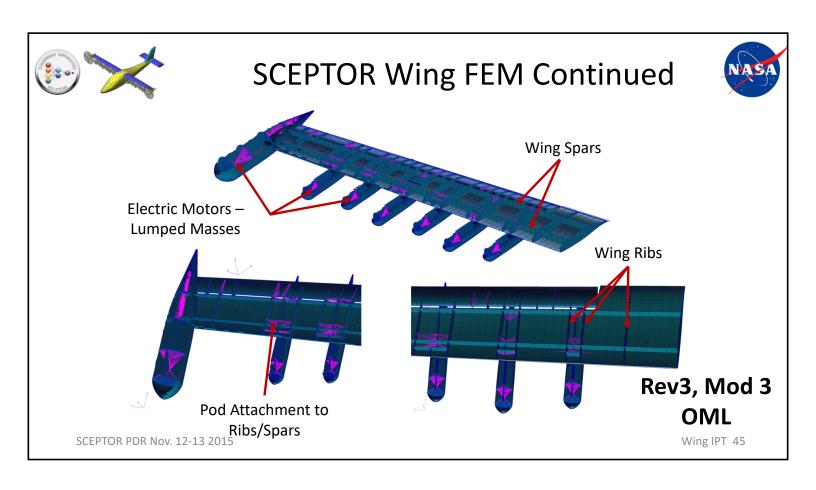


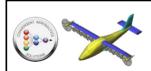
Wing Structural Requirements



- Wing shall be constructed with composite materials (project requirement)
- Weight less than or equal to Tecnam aircraft wings
- Maintain positive margins for all loads cases
 - Based on FAR Part 23 regulations
 - Use design factors of safety of 1.8
- Wing sufficiently rigid as to not cause flutter conditions during all phases of flight
- Attach to existing Tecnam fuselage structure
 - Modifications/Additions to fuselage requires Tecnam approval



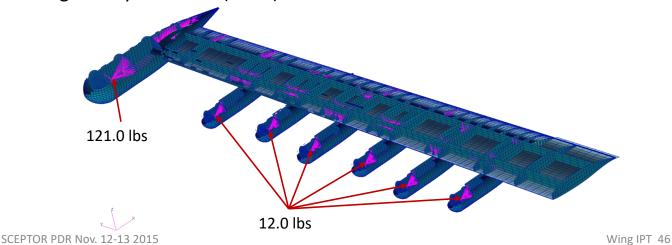




SCEPTOR Wing FEM Continued



- Electric Motors Lumped Masses
 - Includes propeller and hub
 - Rigid Body Elements (RBE3) used to attach electric motors

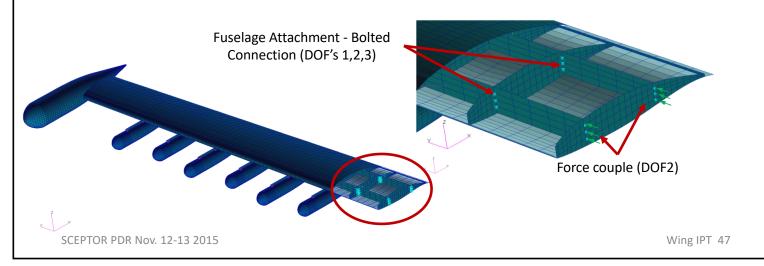


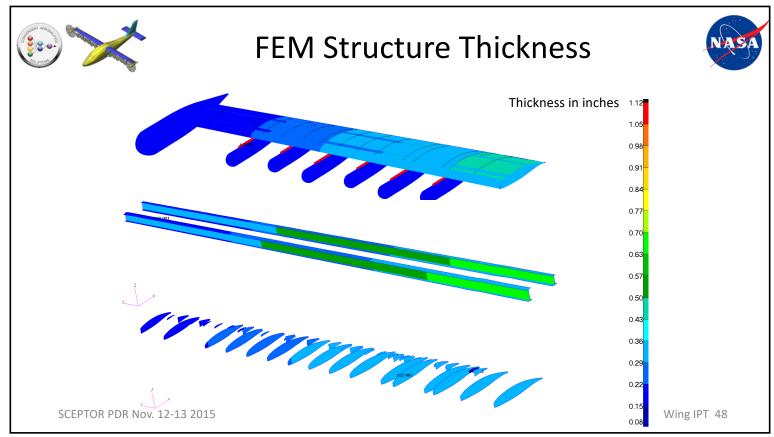


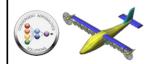
Wing FEM Boundary Conditions



- Currently a bolted joint wing interface with translation degrees of freedom (DOF) fixed at fuselage interface; rotation DOF's are free
- Force couple used to simulate full span wing



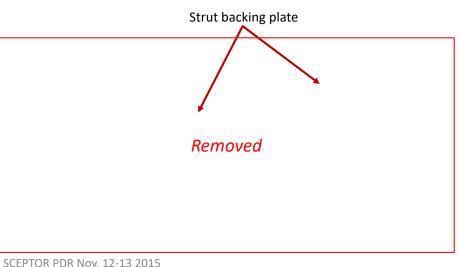


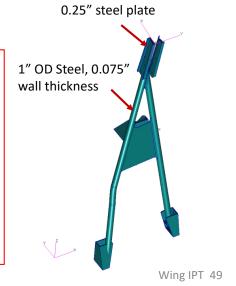


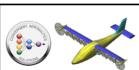
Wing Strut Concept



Wing Strut connects to aft spar and Tecnam Landing gear beam



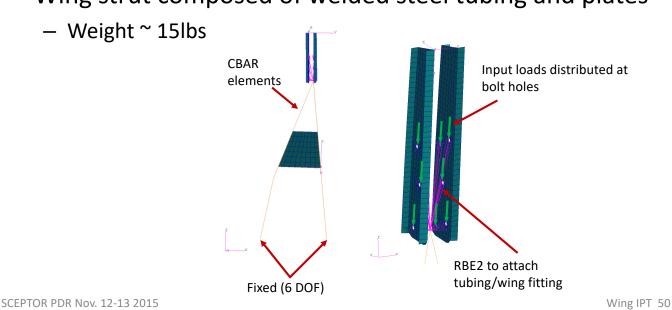




Wing Strut FEM & Boundary Conditions 🐼



Wing strut composed of welded steel tubing and plates



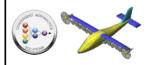


SCEPTOR Load Cases



- Load cases based on Federal Aviation Requirements (FAR) Part 23 (Note + refers to upward, - refers to downward)
 - Up/Down Gust (23.341, Tecnam Report 2006/011): +3.69/-1.78 g
 - Maneuver Loads (23.337, Tecnam Report 2006/011): +3.8g, -1.52g (max)
 - Pull up, Pushover, and Check roll
 - Taxi Bump (23.235, AC25.491): 1.7g 2g
 - Ground Loads and landing (23.473,477-9,481-5,493,497): +3.45g
 - Fatigue Spectrum (AC23/25.571)
 - Crash loads only applicable to fuselage and interior components
- Structural analyses only for new hardware and subsystems mounted to Tecnam aircraft
 - Assumes new hardware designs fit within aircraft structural limits

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Load Sets Analyzed



- Nominal 1g Ground load case (sitting on tarmac)
- Cruise load case (1g):
 - Altitude of 8000 ft, Speed 160 Knots
- Governing load cases analyzed:
 - Limit maneuvers pull-up driving positive load case upward (3.8g)
 - Negative gust load is driving negative load case (-1.78 g)
- Target weight for aircraft is 3000 lbs, semi span wing loads should be:
 - 1500 lbs for 1g cruise case (3000 x (1/2))
 - 2670 lbs for -1.78 negative gust case (1500 lbs x -1.78g)
 - 5700 lbs for limit maneuver pull up (1500 x 3.8g)



Factors of Safety



- Project using Factors of Safety (FS) of 1.8
 - Based on "Aircraft Structural Safety of Flight Guidelines (G-7123.1-001)"
 - Used for both metallic and composites when verified by proof tests to 120% of flight loads
 - FS of 1.5 would require significant amount of material and system testing
 - Ultimate load = factor of safety x design limit load
 - MS = (allowable load / ultimate load) 1

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Wing and Strut Material Properties



- Project using Toray plain weave carbon fiber fabrics
 - Epoxy prepreg layers
- FEM composite shell elements built in ply layers with PCOMP cards (includes strand orientation)
- Shell Element Orthotropic Material Properties (MAT8) for composite lamina:
 - E₁: 22.0_E6 psi, E₂: 1.30_E6 psi
 - v_{12} : 0.3
 - G₁₂: 1.00_€6 psi
 - ρ : 0.056 lbs/in³
- Divinycell used as wing skin core materials
- Use nominal steel (AISI 4130) properties for wing strut

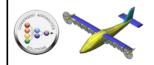


Material Allowables



- Composite laminate allowable used for preliminary design are 100 ksi
 - Toray material data sheets show material limits well above 150 ksi
 - 100ksi Covers material knock-down factors, greater than 50%
 - Based on previous coupon testing values and confidence in composite part fabrication/workmanship
 - Joby Aviation and project feels material allowable is conservative
- Laminate coupon testing planned during fabric/component layups
- Material allowable for Steel (AISI 4130 Steel): 63.1 ksi yield, 97.2 ksi ultimate
 - www.matweb.com and MMPDS-08

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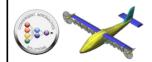


Analysis Assumptions



Wing IPT 55

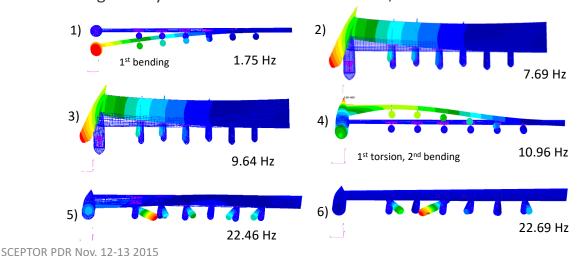
- Bolted joint boundary condition at wing is conservative
 - All moments are dumped into joint, where spar should carry a good portion of the moments in reality
- Scaling the cruise (1g) load case to 3.8g is conservative
 - Actual wing will stall well before reaching 3.8g (except in dive)
- Flight and ground loads will remain in Tecnam fuselage loads envelope
- Damping in transient analyses of 2%
 - Composite damping typically very low (0.5 1% damping)
 - Core materials, wiring, and electronics provide increase in damping



Wing Modal Analysis



- Wing dynamic properties characterized by normal modes (NASTRAN SOL 103) with fixed boundary conditions
 - six rigid body modes in free-free condition, no mechanisms



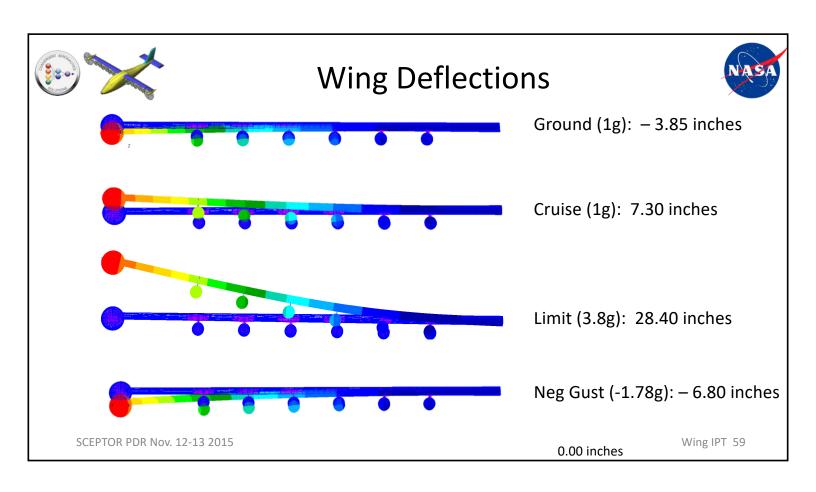
Wing IPT 57

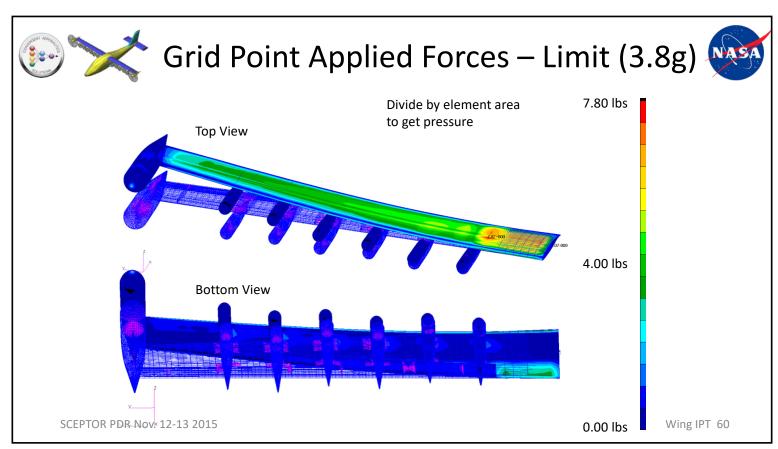


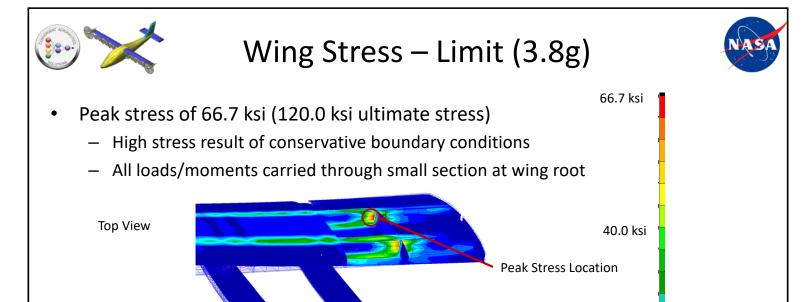
Load Cases



- Ground and Gust cases
 - Linear static solution (NASTRAN SOL 101)
 - Fixed boundary conditions at wing root
 - Loads applied as gravitation load to entire wing structure
- Cruise and limit maneuver cases used CFD loads for cruise conditions provided by Aero-elasticity group
 - Loads included grid point force and moment cards
 - Cruise condition at 8000 ft and 160 knots
- Force and moment cards provided as load factors in terms of dynamic pressure, Q
 - Q at cruise is approximately 0.47 psi, multiplied load factors by Q to yield appropriate external force loads
 - Scaled Q for limit maneuver is 1.79 psi, multiplied load factors by Q to yield appropriate external force loads





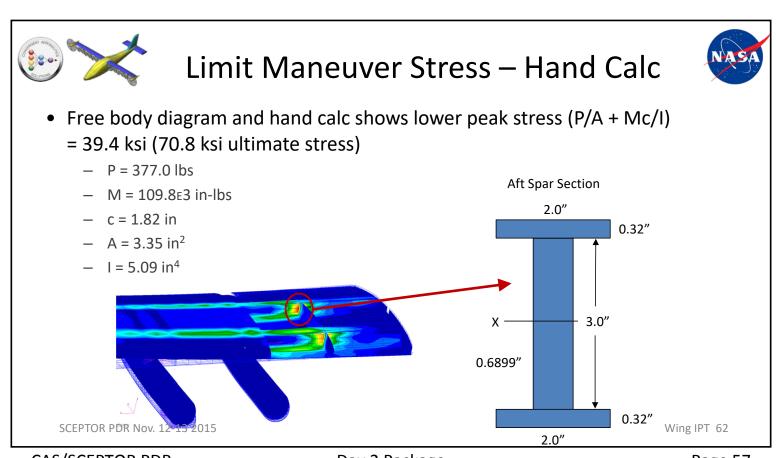


Wing IPT 61

0.00 psi

Bottom View

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Wing Stress and Margins Summary



- Wing primary structure analyzed for driving load cases (FS of 1.8), MS = (allowable load / ultimate load) – 1
- Wing maintains positive margins for all load cases*
 - *Boundary conditions are considered conservative for limit maneuver case, causing negative margin

Hand calc for limit load where full wing spar can take moments show positive margins

Wing Load Cases	Design Limit Stress (psi)	Allowable (psi)	Margins
Ground Static (1g)	9,900	100,000	9.10
Cruise (1g)	17,100	100,000	4.85
Limit Maneuver Pull-up (3.8g)	120,000	100,000	-0.17
*Limit Maneuver Hand Calc	70,800	100,000	0.41
Negative Gust (-1.78g)	17,500	100,000	4.71
Factor of Cafaty	1 0		

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Wing IPT 63



Aft Spar Attach Strut Load Cases



- Linear static solution (NASTRAN SOL 101)
- Fixed boundary conditions at connection to Tecnam landing gear beam
 - Analysis assumes ALL wing load goes through strut (very conservative)
- Limit pull up maneuver: 3.8g (5700 lbs tension)
- Negative Gust: -1.78g (513.9 lbs compression)



Wing Strut Peak Stress Results



 Peak stresses were observed for the 3.8g pull-up maneuver: Max Bar Stress 31.9_E3 psi (57.4_E3 psi ultimate stress)

Maximum Shell Stresses Maximum Combined
Bar Stresses

19.2 ksi 4.64 ksi

31.9 ksi

Wing IPT 65

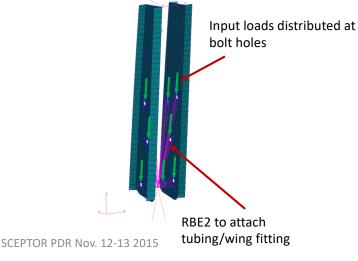


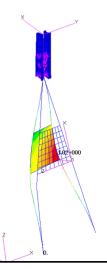
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Wing Strut Buckling Analysis



- 6 kips vertical load applied at wing interface (conservative, should never be higher than 2000lbs)
- Eigenvalues of 4.5 indicate buckling would occur around 30 kips





Wing IPT 66



Strut Stress and Margins Summary

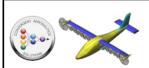


- Material allowable for Steel (AISI 4130 Steel): 63.1 ksi yield, 97.2 ksi ultimate
 - Peak ultimate stress for 3.8g case (57,400 psi)
 - Peak ultimate stress for negative gust -1.78g case (3,200 psi)

Strut Load Cases	Actual (psi)	Allowab	le (psi)	Margins
Limit Dull up (2.9a)	21 000	yield	63,100	0.10
Limit Pull-up (3.8g)	31,900	ultimate	97,200	0.69
Negative Cust (170m)	1,770	yield	63,100	18.81
Negative Gust (-1.78g)		ultimate	97,200	29.51
Factor of Safety	1.8			

 Buckling analysis shows wing strut can easily handle conservative wing loads without buckling

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Wing Structural Analysis Summary



- SCEPTOR wing structure analyzed for ground, cruise, and driving load cases
 - Static ground (1g), cruise (1g), limit pull-up (3.8g), and negative gust (-1.78g)
- Two spar configuration shows positive margins of safety for all the driving load cases analyzed
 - Peak wing stresses occurs at the wing root
- Preliminary wing strut design shows positive margins and low likelihood for buckling
 - Peak wing strut stress occurs at interface to landing gear support beam



Forward Work



- Address wing root high stress (couple of options)
 - Refine wing interface design to fuselage to allow wing spar to carry moments through wing spar or increase root spar thicknesses
- Address load cases that have not been analyzed (take-off bump, check rolls, etc.
 - Take-off bump expected to be another driving (dynamic) load case
- Increase design and structural analysis fidelity in wing and interface to Tecnam aircraft
 - Incorporate flap and aileron structure
 - Refine electric pod mounting structure in FEM
 - Increase fidelity on Wing interface strut
 - Secondary mounting structure for wiring, instrumentation, batteries (?), etc.

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Aeroelasticity Analysis

NASA LaRC Jen Heeg



Technical Performance Metrics



- Tip deflection
- Wing twist
- **Flutter**
 - Divergence
 - Wing
 - Body freedom
 - Static margin instability
 - Whirl (Propeller)
 - Control surface

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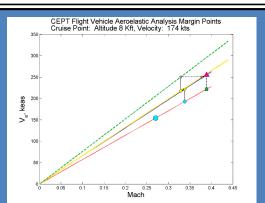


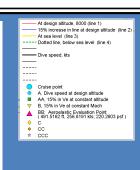
Aeroelasticity Design Considerations

- Flutter-free throughout flight envelope, extended to aeroelastic evaluation limits
- Static aeroelastic analysis results and trends assessed against limits on deformation
- Evaluating cruise configuration at:
 - · Nominal cruise condition (150 kts)
 - High-speed cruise condition (174 kts)

Aeroelastic clearance points

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FAR AC 25.629 & AFRC requirement is

- 18% margin in dive speed (kts); OR
- 66% margin in dive speed (keas); OR
- 76 % margin in dynamic pressure

AE analysis point #1 = FAR requirement (1.53 psi = 10.5KPa= 254 keas = 287 kts = 500 ft altitude at cruise speed)

AE analysis point #2 = increased condition for design margin =100% margin in dynamic pressure

(1.75 psi = 12KPa = 272 keas = 307 kts = -13Kft altitude at cruise speed)

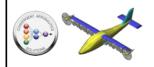


Summary of Flutter Analyses



- We are not flutter critical for any of the baseline configurations analyzed to date.
- Divergence is the critical instability for the baseline fuselage location and boundary conditions; The flutter mechanism involves both the wing vertical first bending mode and the short period mode for free-free cases.
- Including the rigid body modes in the flutter analysis INCREASES the divergence dynamic pressure.
- Full span analyses yield identical flutter speeds (identical to the semi-span symmetric flutter results)
- Cruciform modeling of nacelles degraded results relative to CFD for high-lift nacelle regions; improved results for tip nacelle
- Hump mode flutter often occurs for pod modes. However, structural modeling of the connections from pods to wing is not yet representative of real structure.

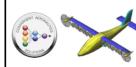
SCEPTOR PDR Nov. 12-13 2015 Wing IPT 73



Near-term Analysis Plans



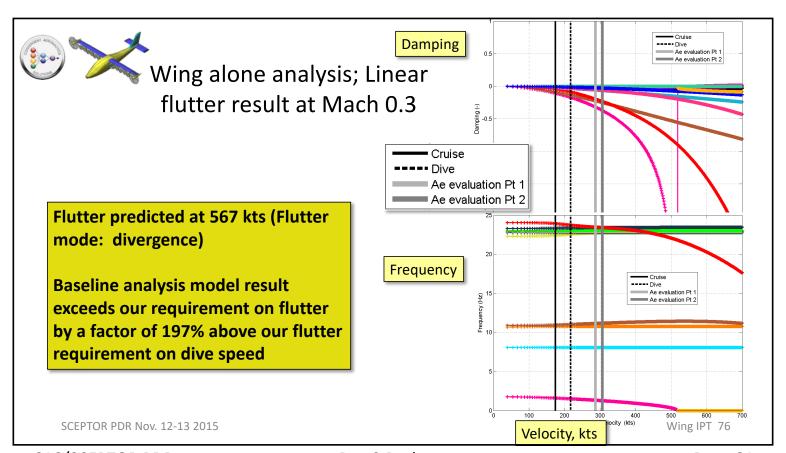
- Analyze aircraft with horizontal tail present. Preliminary results presented here.
- Perform trim analyses; attempt to generate dynamic stability derivatives from the linear aeroelastic solution.
- CFD analyses at benchmarking points and for correction factors.
- Update structural model to keep pace with current design process.
- Examine take-off or landing configuration.

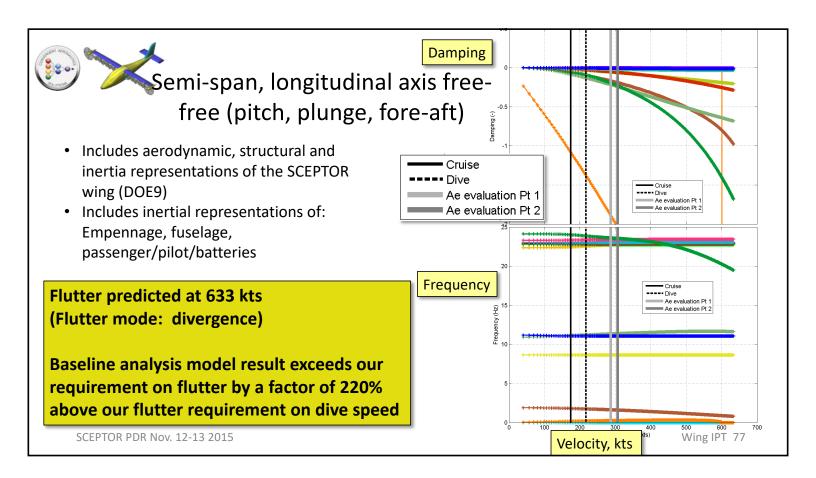


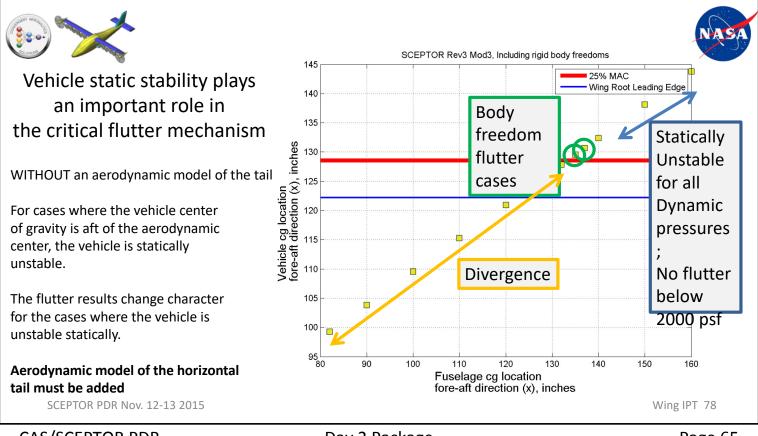
😥 🔭 Baseline Configuration Analyses 💖

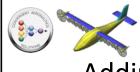


Description	Boundary Condition	Aerodynamic modeling	Inertial modeling	Flutter prediction V (kts at 8Kft)
Semi-span	Cantilevered	Wing	Wing	567
Semi-span	Longitudinal axes free- free	Wing	Wing Fuselage Empennage Pilot/Passengers/Batteries	633
Full span	Free-free	Wing	As above	633
Semi-span	Longitudinal axes free- free	Wing Horizontal tail	As above	865



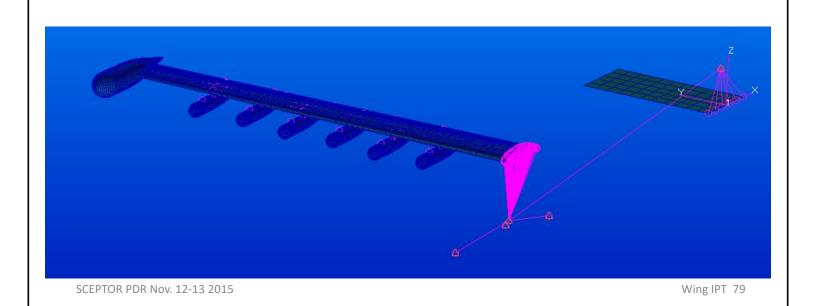


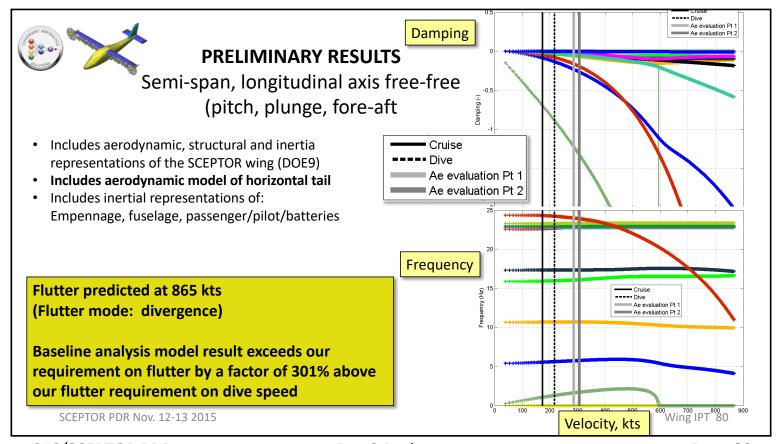




Current work: (11/9/2015)

Adding an aerodynamic model of the horizontal tail







Whirl Flutter

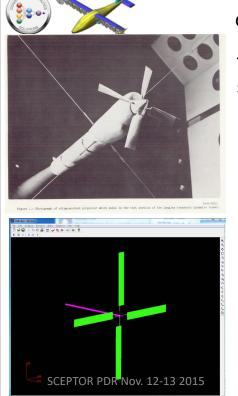
Green: Reporting on at PDR
Yelow: In progress, but no report at PDR
Red: Not completed to the point where we can report

- Progress since SRR:
 - The whirl flutter code previously being used (PASTA), which gave inconsistent results and trends, is no longer in the mix.
 - Modified Matlab code which was also giving inconsistent results and trends.
 - Performed benchmarking against experimental data using
 - CΔMRΔΓ
 - DYMORE
 - Matlab
 - Evaluated baseline SCEPTOR configuration with CAMRAD.
- Tasks
 - Testcase from Bennett and Bland
 - Baseline configuration of SCEPTOR configuration (DOE9)
 - CAMRAD
 - DYMORE
 - Matlab
 - Variations in nacelle yaw and pitch stiffness

Priorities:

- Generate a whirl flutter equivalent beam model for performing DYMORE calculations on baseline configuration and as basis for stiffness variations
- Perform stiffness variations of the pod yaw and pitch nacelle for the tip pod
- Issues and discussion:
 - FEM does not have real structure representing the connections of the pods to the wing. The stiffness of these components will govern the whirl flutter solution.
 - Without a simplified model, parametric variations of the stiffnesses are difficult/questionable
 - Delaying variations of stiffnesses until structural model update with representation of the hardware connection

SCEPTOR PDR Nov. 12-13 2015 Wing IPT 81



Whirl flutter methodology test case analyses completed comparing 3 codes with experimental data



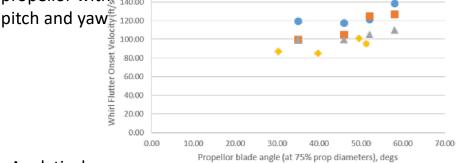
DYMORE

▲ MATLAB

CAMRAD

Test article:

sting-mounted
Pylon Nacelle Benchmarking Case, Stiffness #1: Whirl Flutter
nacelle &
Results for Windmilling Case
propellor with



Analytical model, shown in DYMORE

All 3 analysis processes show reasonable agreement and trends

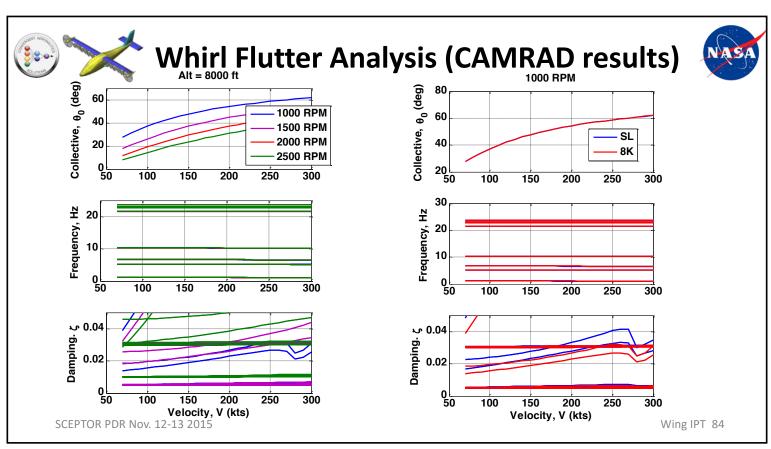
Wing IPT 82

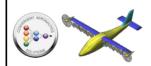


Whirl Flutter Analysis (CAMRAD results)



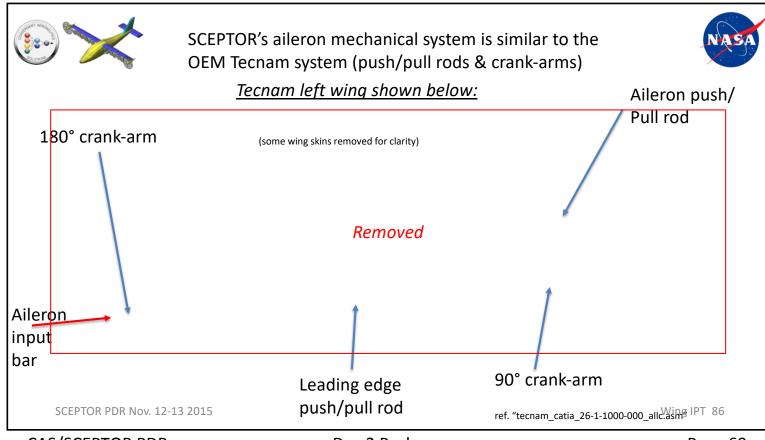
- Analysis of the tip propeller whirl flutter using CAMRAD II
- Rev3mod3 wing structural model
- Wind milling propeller analysis (most conservative)
- Four RPM cases: 1000 2500 RPM
- Each case examined
 - Velocity variation
 - Blade pitch adjusted to zero net torque
- FAR-23 Sec. 629 requires flutter clearance to 1.2 VD
- No negative eigenvalues noted up to 450 kts
- Increase in altitude appears to reduce stability
- · Reduction in RPM appears to reduce stability
- Structural uncertainty to be examined via
 - Mode frequency variation
 - Mode shape amplitude variation



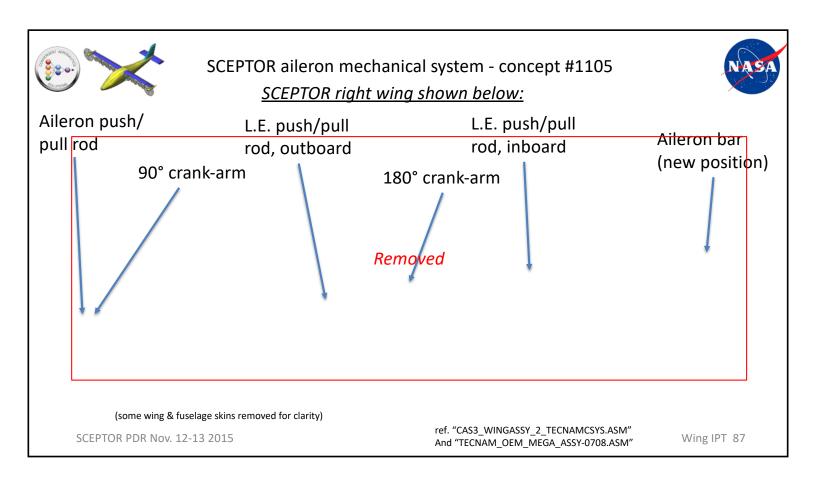


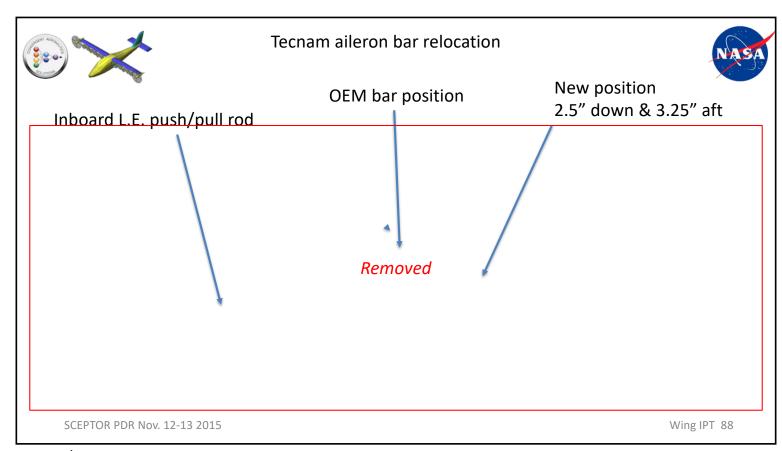


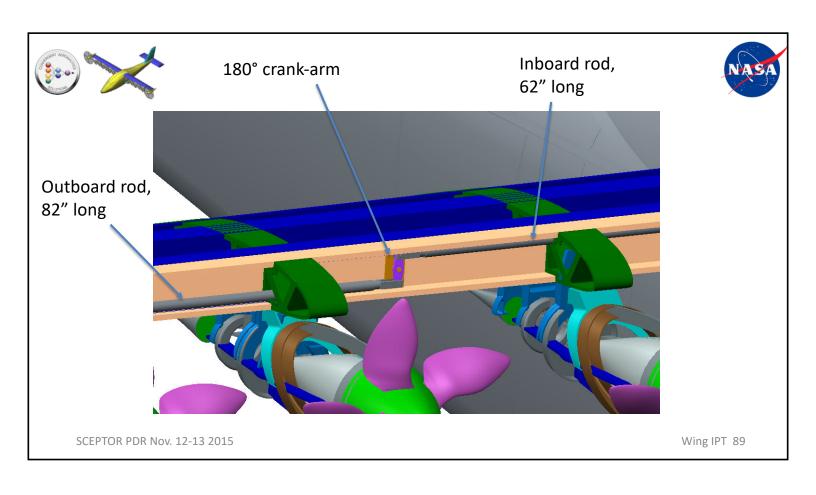
aileron mechanical concept #1105 W. M. Langford NASA LaRC ED

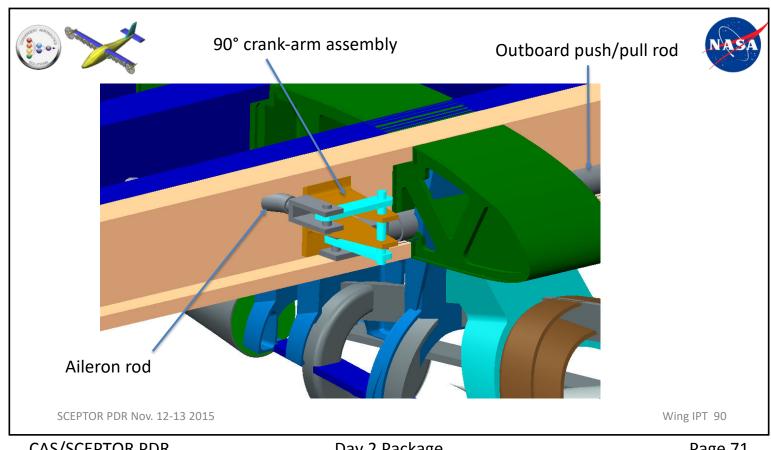


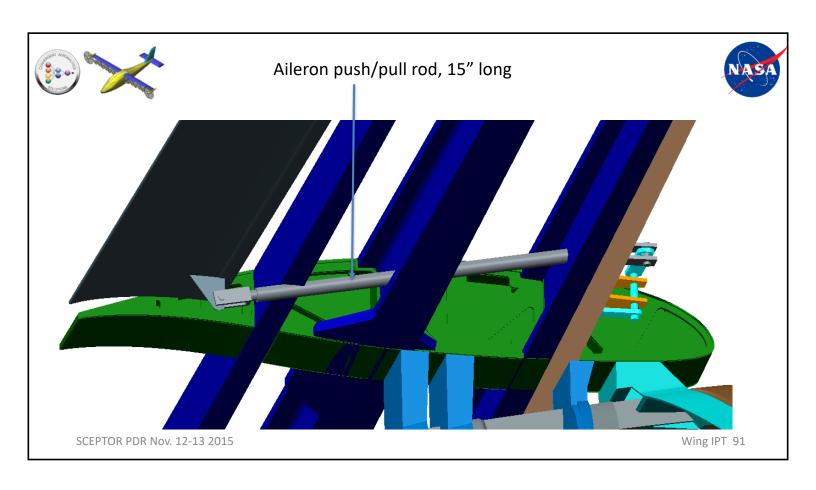
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Roles and Responsibilities



	LaRC	AFRC	ESAero / Joby	Tecnam
Wing Aerodynamic Design	Х			
Wing Structural Design	Х			
Wing / Fuselage Attachment Design	Х			
Wing Primary Structure Analysis	Х			
Aileron / Flap Design	Х			
High-Lift Motor Nacelle and Structure Design	Х		Х	
Cruise Motor Nacelle and Structure Design	Х		Х	
Aeroelasticty Analysis	Х	Х		
Loads Definition	Х	Х		
Structural Testing		Х		
Aeroelastic Testing		Х		
Wing Fabrication			Х	
Wing Attachment Structure Fabrication			Х	Х

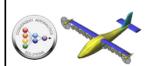


Test & Verification Approach



- Requirements will be verified through a combination of analysis and testing
- All aerodynamic performance requirements will be verified by analysis
- Analysis will be conducted to insure all structure meets the required margin of safety
- Fabrication processes will be verified by SME and step-by-step documentation will be maintained to verify process was followed.
- The final structure will be statically and dynamically tested to meet specifications in AFRC Aircraft Structural Safety of Flight Guidelines G-7123.1.

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Risks



Nº	Title	L	С	Risk Statement	Mitigation Strategies
1	Classical and/or whirl flutter concerns.	Me d	Me d	Given new cruise and distributed motor configuration there is a possibility of insufficiently modeled classical flutter and/or whirl flutter resulting in additional cost and schedule	 Perform flutter analysis. Perform GVT to validate analysis. Use build-up test approach.
2	Wing design does not achieve design drag levels.	Me d	Me d	Given that the SCEPTOR wing design is new and not fully tested, there is a possibility that the drag induced will be greater than expected, and as a result the SCEPTOR Aircraft might not meet performance goal.	 A drag margin of 5% has been used in the design to allow for uncertainty in the design tools and methodology.



Risks



Nº	Title	L	С	Risk Statement	Mitigation Strategies
3	Wing and high-lift motor system does not meet design maximum lift goals.	Me d	Me d	Given that the SCEPTOR wing design is reliant on untested high lift effects, there is a possibility that the SCEPTOR aircraft will not meet design goal stall speed, and as a result the SCEPTOR Aircraft might not meet performance goal.	 SCEPTOR operational stall speed will be adjusted to meet actual stall speed achieved. Actual stall speed achieved will be used as basis for further research and tool validation to be used in the design of future SCEPTOR concepts.
4	Wing has sharp stall characteristics.	Me d	Me d	Given that the SCEPTOR wing design is new and not fully tested, there is a possibility that the aircraft could have sharp stall resulting in undesirable flying qualities near stall.	 Conduct SCEPTOR aircraft stall tests at high altitude to document the stall characteristics of the aircraft at a safe altitude. Adjust operating speeds to fly at a sufficiently safe speed above stall for all performance tests.

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Issues & Resolutions



Issue	Resolution Plan
NAS Resource computer time, priority, and job turn around time	Ask for higher priority / find other resources on local clusters
Uncertainty with 2D and 3D computer codes in predicting maximum lift	Utilize margins in airfoil and wing design. Safely test stall performance at altitude and define operating envelope. Validate design codes with HEIST data.
Material fabrication and design allowable verification/validation with available time and budget	Work with AFRC to obtain to reasonable testing and validation process that will meet available budget with acceptable programmatic risk



Major Accomplishments



- High cl, low Reynolds number airfoil and high-lift flap designed
- Primary wing structure concept designed
- High-lift motor structure concept designed
- · Wing-tip cruise motor concept designed
- CFD performance analysis on cruise wing, high lift flap, and blown wing configurations
- FEM constructed and structural analysis conducted on current RevMod3 concept
- Aileron attachment and actuation concept design
- Developed wing flutter analysis process and whirl flutter process, preliminary flutter analysis and whirl flutter analysis conducted

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Go Forward Plan



- Rev 4 detailed CFD performance analysis and loads cases
- Rev 4 detailed wing structural design
- Rev 4 high lift motor mount/nacelle structural design
- Rev 4 wing tip motor structure detailed design.
- Rev 4 Final aeroelastic analysis
- Rev 4 high-lift flap structure/attachment detailed design
- Rev 4 flap actuation detailed design
- Rev 4 aileron structure and actuation detailed design
- Fabrication plan and schedule
- Detailed drawing of power and instrumentation mounting and layout in wing
- Final wing/fuselage attachment structure design
- Preliminary ground test plan (loads testing/GVT)
- · Preliminary flight test plan
- Assessment of CEPT installed wing on aircraft flight performance



Exit Criteria



Subsystem Level Exit Criteria	Evidence
Subsystem level requirements identified and flow to system parents	5-8
Subsystem level designs and analysis exist and are consistent with corresponding requirements	19-26, 34-92
Subsystem level interfaces identified and consistent with design maturity	34-70, 86-91
Project risks identified and mitigation strategies defined	94-96
Test & Verification approach is adequate	27-33, 93
Preliminary hazards adequately addressed and considered in the preliminary design	9-12





SCEPTOR PDR Instrumentation IPT

Ethan Nieman (AFRC x3501)

Doug Howe, Trevor Foster, Phil Osterkamp (ESAero

Removed



Entry Criteria



Subsystem Level Entry Criteria	Evidence
Technical Performance Metrics (TPMs)	Slide 16-17
Preliminary Subsystem Requirements and/or Specifications	Slides 5 – 9
Draft Interface Control Documents	Slides 10 – 12
Design and Analysis	Slides 13 – 25
Drawing Tree	Slide 23
Test and Verification Planning	Slide 27

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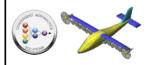


Schedule to CDR



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SCEPTOR PDR Nov. 12-13 2015 Instrumentation IPT 3



Document Status



Doc No.	Doc Type	Document Title	Status
N/A	Plans	Conceptual Measurement List (CML)	Draft
CEPT-004	Plans	Master Measurement List (MML)	In dev.
CEPT-REQ-005	Rqmt.	Instrumentation Subsystem Requirements (SSRD)	Draft
CEPT-PROC-001	Procedure	Phase I Pre-Flight Procedure	Baseline
CEPT-PROC-002	Procedure	Phase I Post-Flight Procedure	Baseline



Requirements (1)



⁄stem eq №	System Requirement Description	Subsys Req №	Subsystem Requirement Description	Verif. Method
1	The CEPT system shall establish a General Aviation (GA) baseline as the performance metric.	N1.1	The instrumentation subsystem shall measure and acquire a specified subset of data in Phase II on the stock wing aircraft configuration.	Test
	The CEPT system shall measure the system performance.	N2.1	The instrumentation subsystem shall measure and acquire performance data from the power subsystem.	Test
		N2.2	The instrumentation subsystem shall measure and acquire performance data from the electric propulsion subsystem.	Test
		N2.3	The instrumentation subsystem shall measure and acquire aerodynamic data of the CEPT aircraft.	Test
•		N2.4	The instrumentation subsystem shall measure and acquire structural data of the CEPT aircraft.	Test
2		N2.5	The instrumentation subsystem shall measure and acquire position and inertial data.	Test
		N2.6	The instrumentation subsystem should acquire video from different subsystems on the CEPT aircraft.	Test
		N2.7	The instrumentation subsystem shall measure and acquire controls data of the CEPT aircraft.	Test
		N2.8	The instrumentation subsystem shall measure and acquire health and status (H&S) data from the instrumentation subsystem.	Test
СЕРТО	OR PDR Nov. 12-13 201			



Requirements (2)



System Req №	System Requirement Description	Subsys Req №	Subsystem Requirement Description	Verif. Method
4	The CEPT system shall list all required measurements in a Master Measurement List (MML).	N4.1	The instrumentation subsystem shall measure and acquire all measurements specified in the MML.	Inspect
6	The CEPT system shall provide throttle control command inputs to the DEP motors.	N6.1	The instrumentation subsystem shall acquire all throttle control commands input to the DEP motors.	Test
7	The CEPT system shall provide throttle control command inputs to the Cruise motors.	N7.1	The instrumentation subsystem shall acquire all throttle control commands input to the Cruise motors.	Test
8	The CEPT system shall report and monitor the Health & Status (H&S) of each DEP motor.	N8.1	The instrumentation subsystem shall acquire all DEP motor H&S available on the motor control communication bus.	Test



Requirements (3)



System Req №	System Requirement Description	Subsys Req №	Subsystem Requirement Description	Verif. Method	
9	The CEPT system shall report and monitor the Health & Status (H&S) of each Cruise motor.	N9.1	he instrumentation subsystem shall acquire all Cruise motor H&S available on the motor control ommunication bus.		
10	The CEPT System shall report and monitor the Health & Status (H&S) of the Battery System.	N10.1	he instrumentation subsystem shall acquire all battery H&S available on the Battery lanagement System (BMS) communication bus.		
	The CEPT system shall provide monitoring of temperature control status for both the Cruise and DEP motors.	provide monitoring of	N14.1 The instrumentation subsystem shall measure and acquire temperature of motor.	The instrumentation subsystem shall measure and acquire temperature data from each DEP motor.	Test
4.4			N14.2	The instrumentation subsystem shall measure and acquire temperature data from each DEP motor controller.	Test
14		N14.3	The instrumentation subsystem shall measure and acquire temperature data from each Cruise motor.	Test	
		N14.4	The instrumentation subsystem shall measure and acquire temperature data from each Cruise motor controller.	Test	

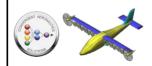
SCEPTOR PDR Nov. 12-13 2015 Instrumentation IPT 7



Requirements (4)



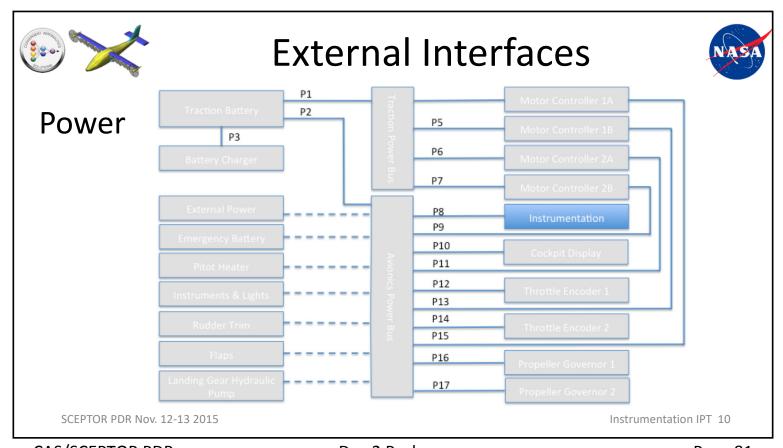
System Req №	System Requirement Description	Subsys Req №	Subsystem Requirement Description	
	The CEPT system shall be controllable and monitored by EGSE during integration and checkout activities.	N15.1	The instrumentation subsystem shall be configurable via software.	Demo
15		N15.2	The instrumentation subsystem configuration files shall be modifiable via an Electrical Ground Support Equipment (EGSE) interface.	Demo
		N15.3	The instrumentation subsystem shall be capable of providing live telemetry data to the EGSE.	Demo
	The CEPT system shall provide on-board recording of all on-board commands and status parameters.	N16.1	The instrumentation subsystem shall record all data acquired.	Test
16		N16.2	The instrumentation subsystem shall record data on solid-state devices.	Test
		N16.3	The instrumentation subsystem shall record data in a compatible format (such as Chapter 4 or 10).	Test

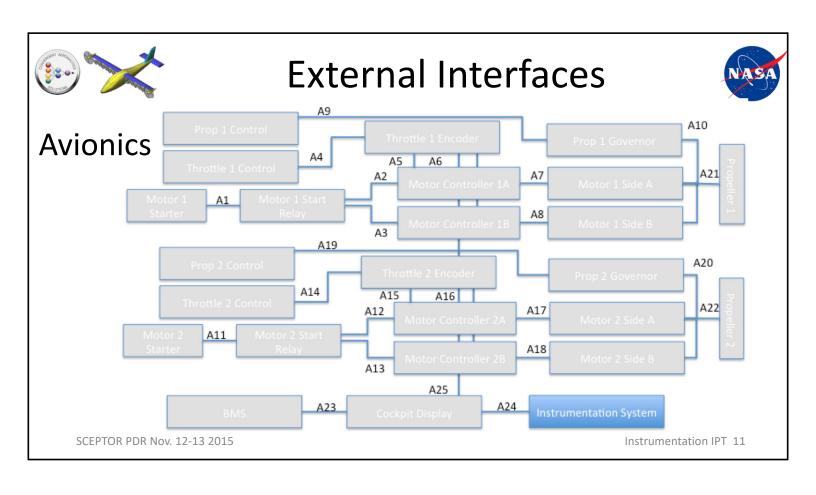


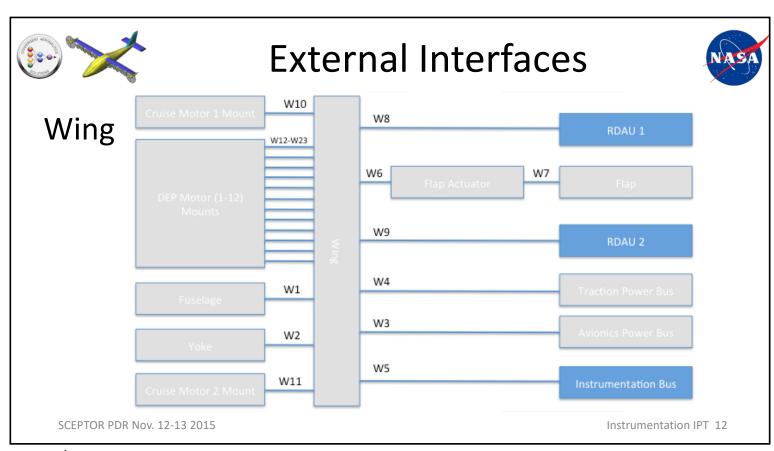
Requirements (5)

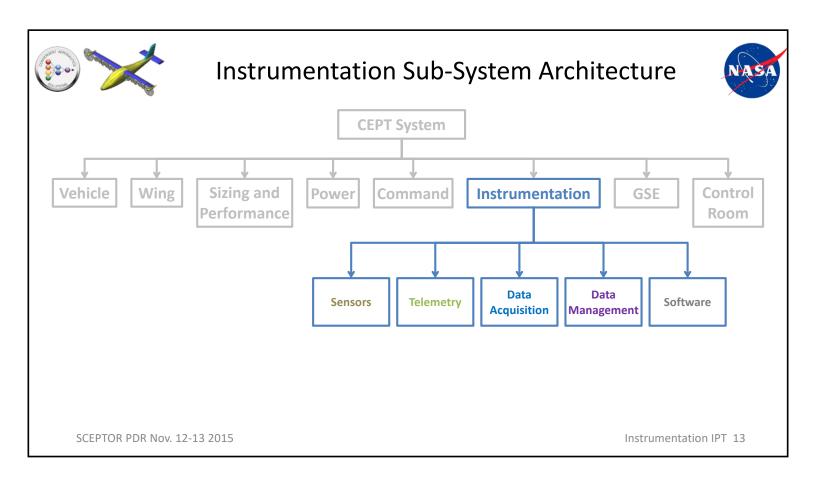


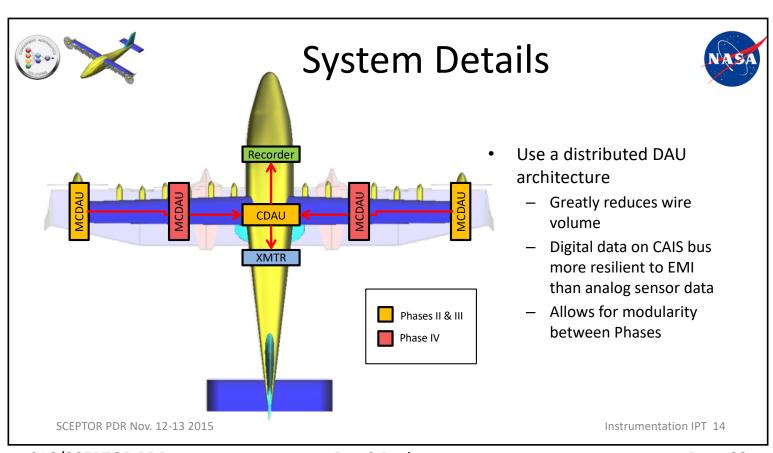
System Req №	System Requirement Description	Subsys Req №	Subsystem Requirement Description	Verif. Method
	The CEPT system shall provide down-link telemetry of all onboard commands and status parameters pertaining to the CEPT-unique mission.	N17.1	The instrumentation subsystem shall encode all acquired data for transmission via telemetry in a compatible format.	Test
17		N17.2	A transmitter shall be used to transmit encoded data to the ground processing station.	Test
24	The CEPT system shall be designed to safely handle single independent faults in critical system components.	N24.1	The instrumentation subsystem should utilize redundancy in its design wherever possible.	Inspect

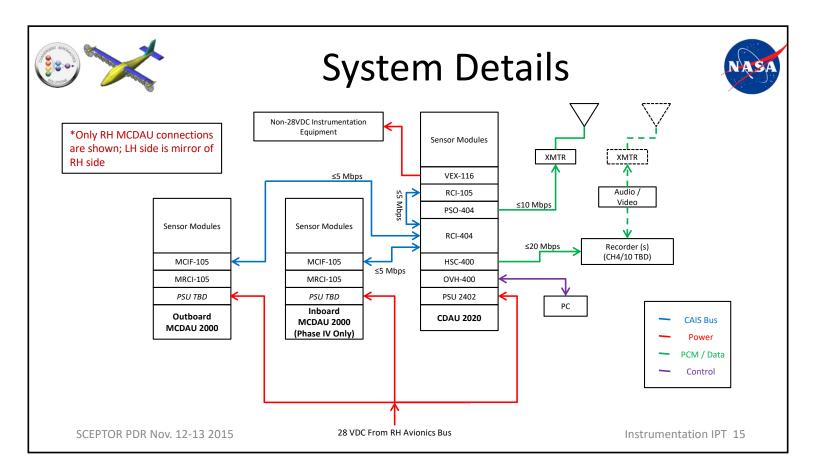
















- Technical Performance Metrics
 - Spatial
 - · Instrumentation Total Weight
 - Instrumentation Volume (per MCDAU-2000)
 - Bandwidth
 - Bandwidth required by TM Map (Mbps/MHz)
 - Percent TM Map populated
 - Onboard Recording
 - Maximum Onboard Recording Duration
 - Expected Recorder File Size
 - Power Consumption
 - Total Instrumentation Power Consumption (wattage)





- Technical Performance Metrics
 - Available to Required Instrumentation Volume
 - Cruise Nacelle Volume Available 3.0 x 5.0 x 8.0 inches (Current Estimate)
 - Cruise Nacelle Volume Required 3.0 x 5.0 x 8.0 inches (Current Estimate)
 - Fuselage Volume Available Co-pilot seat removed and space reserved for instrumentation
 - Fuselage Volume Required One seat space (used for DAQ pallet in Phase I)
 - Instrumentation Required to Available Mass
 - Mass Available 81.82 kg / 180.4 lbs
 - Mass Required 107.39 lbs total
 - 25 lbs Fuselage; 21 lbs wing DAU's (5.25 lbs each); 61.39 lbs harnesses
 - Available to Required Bandwidth
 - Current BW required by CML 4.7 Mbps
 - MCDAU-2000 5 Mbps
 - CDAU-2020 (HSC-400) 20 Mbps (10 Mbps if using PSO-404 card)
 - Frequency Scheduling Typical Max. of 20-30 MHz (11-16 Mbps SOQPSK; 6-10 Mbps FM)
 - Available to Required Power Consumption 500 W required; 700 W Available

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Instrumentation IPT 17



System Details



- Long lead items
 - DAQ chassis and encoders are procurement bottleneck
 - Will have to be purchased before CDR
 - Some sensors may need to be built into wing during manufacturing process (lead time for these are more critical)

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Instrumentation IPT 18





Long Lead Item	Expected Lead Time
TTC Cards/Chassis & Recorder	15 weeks
TM Transmitter	12 weeks
ESPs	4 weeks
GPS (or GPS/INS) Module & Antenna	4 weeks

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Instrumentation IPT 19



System Details



- Baselined Conceptual Measurement List (CML)
 - Less detailed version of an MML
 - Identifies (per parameter)
 - Requested sample rate
 - EU min, max, units
 - Technical POCs
 - Relevant subsystem/structure
 - Estimated channel count & proposed implementation
 - Classification (Safety Critical, Mission Critical, Desired)





Category	Measurement/Data 🔻	Subsystem / Structu	Sample Rate SP			Engineering U	Estimated Channels Required (Phase I	Technical POCs
Aerodynamic	Cabin Interior Acoustics	Fuselage	8000	20	120	dBA	2	Nick Borer
Aerodynamic	Calibrated Airspeed	Fuselage	50	0	400	knots	2	Roger Truax; Nick Borer; Dave Cox
Aerodynamic	Chordwise Steady Pressure	Wing	100	-2.5	2.5	psid	64	Jeff Viken
Aerodynamic	Spanwise Steady Pressure	Wing	100	-2.5	2.5	psid	32	Jeff Viken
Aerodynamic	Unsteady Pressure (Microphone)	Wing	5000	0	15	psia	8	Jeff Viken
Aerodynamic	Angle of Attack	Fuselage	10	-30	30	deg	1	Jeff Viken; Dave Cox
Aerodynamic	Angle of Sideslip	Fuselage	10	-30	30	deg	1	Jeff Viken; Dave Cox
Aerodynamic	Air pressure / pressure altitude	Fuselage	50	-1000	30000	ft	0	Roger Truax; Nick Borer
Aerodynamic	DEP Motor Steady Pressure	DEP Motors	10	-2.5	2.5	psid	32	Jeff Viken
Aerodynamic	Tufts	Wing	N/A	NIA	NA	N/A	1(video)	Jeff Viken
Battery	BMS CAN Bus Data	Power	10	NIA	NA	N/A	2	Sean Clarke
Battery	Battery Pack Output Voltage	Power	100	0	TBD	Vdc / Vac	10	Sean Clarke; Nick Borer
Battery	Battery Pack Output Current	Power	100	0	TBD	Vdc / Vac	10	Sean Clarke; Nick Borer
Battery	Output Voltage per DC converter	Power	100	0	TBD	Vdc / Vac	2	Sean Clarke
Battery	Output Current per DC converter	Power	100	0	TBD	Vdc / Vac	2	Sean Clarke
Control	Aileron Deflection	Fuselage	10	-30	30	deg	1	Dave Cox
Control	Elevator Deflection	Fuselage	10	-30	30	deg	1	Dave Cox
Control	Rudder Deflection	Fuselage	10	-30	30	deg	1	Dave Cox
Control	Elevator Trim Deflection	Fuselage	10	-30	30	deg	1	Dave Cox
Control	Rudder Trim Deflection	Fuselage	10	-30	30	deg	1	Dave Cox
Control	DEP Throttle (Get from CAN Bus)	DEP Motors	10	TBD	TBD	TBD	2	Dave Cox; Nick Borer; Sean Clarke
Control	Cruise Throttle (Get from CAN Bus)	Cruise Motors	10	TBD	TBD	TBD	NA	Dave Cox; Nick Borer; Sean Clarke
Control	Controller CAN Bus Data	Cruise Motors	10	N/A	N/A	N/A	1	Sean Clarke; Dave Cox
Control	Flap deflection	Fuselage	10	-30	30	deg	1	Dave Cox
Control	Landing Gear Status	Fuselage	10	N/A	N/A	boolean	1	Dave Cox; Nick Borer;
GPS	Altitude	Fuselage	10	-1000	30000	ft	1	Everyone
GPS	Longitude	Fuselage	10	-180	180	dms	NA	Everyone
GPS	Latitude	Fuselage	10	-90	90	dms	NA	Everyone
GPS	Time	Fuselage	10	NA	NA	UTC	NA	Everyone
GPS	Ground Speed (Vector components)	Fuselage	10	0	300	knots	NA	Everyone
GPS	Number of Satellites	Fuselage	10	N/A	N/A	integer	NA	Everyone
GPS	Almanac Status	Fuselage	10	N/A	N/A	boolean	NA	Everyone
GPS	Bearing WRT True North	Fuselage	10	0	360	deg	NA	Everyone
Inertial	Maneuver Loads (CG Accels)	Fuselage	50	-5	5	a	3	Everyone
Inertial	Roll/Pitch/Yaw Rates	Fuselage	50	-100	100	deg/s	3	Everyone
Inertial	Euler Angles	Fuselage	50	0	360	deg	2	Everyone
Inertial	Bearing (Magnetic)	Fuselage	50	0	360	dea	1	Everyone

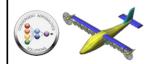
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System Details

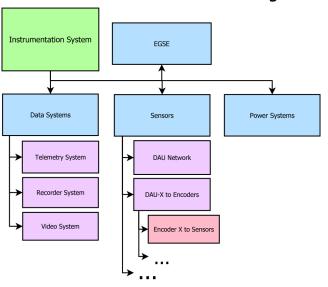


Category 🟋	Measurement/Data	Subsystem / Structu	Sample Rate SP 🕌	EU Range 🕌	EU Range I 🕌	Engineering U	Estimated Channels Required (Phase I	Technical POCs
Propulsion	DEP Motor Thrust	DEP Motors	10	0	500	lbf	8	Nick Borer
Propulsion	Cruise Motor Thrust	Cruise Motors	10	0	2000	lbf	2	Nick Borer
Propulsion	DEP Motor Torque	DEP Motors	10	0	1000	lbf-in	8	Nick Borer
Propulsion	Cruise Motor Torque	Cruise Motors	10	0	4000	lbf-in	2	Nick Borer
Propulsion	DEP Prop RPM	DEP Motors	100-10000	0	8000	RPM	8	Roger Truax; Sean Clarke; Nick Borer
Propulsion	Cruise Prop RPM	Cruise Motors	100-10000	0	8000	RPM	2	Roger Truax; Sean Clarke; Nick Borer
Propulsion	DEP Fold Status	DEP Motors	10	0	1	boolean	8	Nick Borer; Sean Clarke; Roger Truax
Propulsion	Cruise Prop Angle	Cruise Motors	10	0	50	deg	2	Nick Borer; Sean Clarke; Roger Truax
Propulsion	Cruise Motor Input Voltage	Cruise Motors	100	0	500	Vac	2	Sean Clarke
Propulsion	Cruise Motor Input Current	Cruise Motors	100	0	200	A	2	Sean Clarke
Propulsion	Cruise Motor Controller Input Voltage	Cruise Motors	100	0	500	Vac	2	Sean Clarke
Propulsion	Cruise Motor Controller Input Current	Cruise Motors	100	0	200	A	2	Sean Clarke
Propulsion	DEP Motor Input Voltage	DEP Motors	100	0	500	Vac	8	Sean Clarke
Propulsion	DEP Motor Input Current	DEP Motors	100	0	200	A	8	Sean Clarke
Propulsion	DEP Motor Controller Input Voltage	DEP Motors	100	0	500	Vac	8	Sean Clarke
Propulsion	DEP Motor Controller Input Current	DEP Motors	100	0	200	A	8	Sean Clarke
Thermal	DAQ Temperature	Instrumentation	10	0	250	F	5	Ethan Nieman; Doug Howe
Thermal	DEP Controller Temperature	DEP Motors	10	0	250	F	16	Nick Borer; Sean Clarke
Thermal	Cruise Controller Temperature	Cruise Motors	10	0	250	F	4	Nick Borer; Sean Clarke
Thermal	Cruise Motor Temperature	Cruise Motors	10	0	250	F	4	Nick Borer; Sean Clarke
Thermal	DEP Motor Temperautre	DEP Motors	10	0	250	F	16	Nick Borer; Sean Clarke
Thermal	Cruise Motor Heatsink Temperature	Cooling System	10	0	250	F	4	Nick Borer; Sean Clarke
Thermal	Temp per DC converter (12 V supply)	Power	10	0	250	F	2	Sean Clarke
Thermal	Ambient Outside Air Temperature	Fuselage	10	0	250	F	2	Everyone
Thermal	Pressure transducer temperatures (ESP and PPT)	Fuselage	10	n	250	F	2	Ethan Nieman: Doug Howe





SCEPTOR Instrumentation Drawing Tree



- All drawings will be numbered according to Drawing Tree
- Each set of digits in the string represents a level (e.g. drawing for encodersensor connections might be CEPT-05020307)

Instrumentation IPT 23



SCEPTOR PDR Nov. 12-13 2015

System Details



- Standards / processes being used
 - Software Management
 - · Practiced this with Rental Activity and LEAPTech
 - Use GitLab (AFRC internal git server) as integrated DR, CCR, and code repository
 - Used consistent naming convention: new date to indicate hardware/TM map change, new letter (rev) to indicate soft changes (calibration coef., derived parameters, etc.)
 - CEPT-007 Environmental Test Plan (ref. DCP-O-018, DO-160)

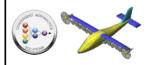




- Lessons Learned from LEAPTech and Phase I
 - Must place access panels in a way that allows for nondestructive modification/part replacement
 - CAD model Wing Instrumentation to track volume available/used
 - Take advantage of distributed DAUs to minimize harness volume
 - Knowledge of how to route wire in Tecnam fuselage and instrument basic airframe & controls
 - Must use proper connector and harness shielding to protect data from EMI caused by motors

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Instrumentation IPT 25



Roles and Responsibilities



- Procurement ESAero
- MML Development/Drawings NASA AFRC/ESAero
- Functional & Environmental Testing (Component Tests) – NASA AFRC
- Instrumentation Integration
 - Phase II & III Integration TBD Sub Contractor of ESAero
 - Phase III Wing Fabrication TBD Sub Contractor of ESAero
- System-Level Testing and Verification NASA AFRC



Test & Verification Approach



- Functional and Environmental Testing of all instrumentation equipment (component tests)
- Procedures for subsystem testing and system testing (HRT, CST) will be written and performed to verify instrumentation requirements

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Instrumentation IPT 27



Risks



Nº	Title	L	С	Risk Statement	Mitigation Strategies
1	Instrumentation Cost May Exceed Budget	Med	High	Given a limited budget for instrumentation, there is a possibility of the planned instrumentation system overrunning its budget, resulting in a reduced configuration that produces a system that doesn't meet all safety and mission requirements.	 Carefully prioritize all measurements in the MML; and, as a project, identify which are unnecessary for meeting project safety and mission requirements. Identify existing equipment that can be reused without increasing risk of mission success.
2	Purchasing DAQ Hardware Before CDR	Low	High	Given the long lead time in procuring DAQ hardware (and therefor the need to procure before CDR), there is a possibility of selecting the wrong items, resulting in a system that doesn't meet all requirements.	 Investigate what decisions were made and why regarding DAQ hardware for other NASA projects. Design a flexible architecture (spare channels where possible, choice of TM data rates, etc.) Communicate with other subsystems to identify likely or potential changes in requirements Conduct System Table Top Review (STTR) prior to procuring long lead items.

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Instrumentation IPT 28



Issues & Resolutions



Issue	Resolution Plan
Volume Available/Accessibility in Wing	Finalize access panel location with Wing IPT; use distributed DAUs to minimize harness volume
EMI	Implement appropriate shielding with harnesses and connectors; minimize wire length for analog signals

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Instrumentation IPT 29



Major Accomplishments



- Baselined CML
- Identified items for reuse (from LEAPTech, Phase I)
- Established lead times for critical items
- Instrumented rental Tecnam and collected flight data
 - Lot of experience/lessons learned on how to wire Tecnam airframe (access panels), locate position transducers to measure control surface deflection, yoke force balance
 - Familiarity with DAQ architecture that is planned for use in later phases



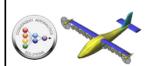
Go Forward Plan



- Migrate CML items to MML
- Finalized list of required equipment and materials (ready for procurement)
- Completed drawings (Phase II & III)
- Internal Peer Review
- Finalize physical DAQ & access panel location on new wing with Structures
- Solid model wing instrumentation (DAQs, connectors, and harnesses)

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Instrumentation IPT 31



Exit Criteria



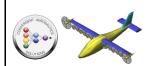
Subsystem Level Exit Criteria	Evidence
Subsystem level requirements identified and flow to system parents	Slides 5 – 9
Subsystem level designs and analysis exist and are consistent with corresponding requirements	Slides 13 – 25
Subsystem level interfaces identified and consistent with design maturity	Slides 10 – 12
Project risks identified and mitigation strategies defined	Slide 28
Test & Verification approach is adequate	Slide 27
Preliminary hazards adequately addressed and considered in the preliminary design	N/A





System & Subsystem Test and Verification

Yohan Lin 661-276-3155 yohan.lin@nasa.gov



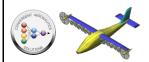
Document Status



Draft verification and test plan released

Doc No.	Doc Type	Document Title	Status
CEPT-006	Plan	SCEPTOR System & Subsystem Verification Test Plan	Draft

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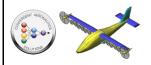
Roles and Responsibilities



- NASA AFRC responsible for overall verification of system requirements fulfillment (system level)
 - Project Chief Engineer
 - Project Lead Vehicle Integration & Test Engineer
- IPT leads responsible for overseeing subsystem requirements verification
 - IPT Lead
 - Project Lead Vehicle Integration & Test Engineer

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System and Subsystem Test and Verification 3



Types of Verification



- Inspection
- Analysis
- Test
 - Functional
 - Environmental acceptance
 - Proto qualification (stress test, higher than expected environment, can be used for flight if acceptance tested prior to use)
 - Failure Modes and Effects Test
- Demonstration
- Simulation

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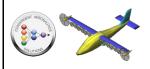
System/Subsystem Test & Verification Approach



- Requirements are developed by each IPT
- Responsible organization formulates procedures
- Procedures that map to appropriate requirements are peer reviewed, updated and signed off
- A requirements verification matrix card is filled out for each test that satisfies a set of system/subsystem requirements
- For system level tests, provide the AFRC project chief engineer and lead vehicle integration & test engineer the system test report, the requirements verification matrix card, and a copy of the as-run test procedure
- Discrepancy Reports are required for addressing any anomalies that arise which require changes in software or hardware. Retest and submit STR, procedure, and verification card

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System and Subsystem Test and Verification 5

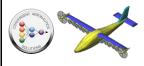


System/Subsystem Test & Verification Approach



- For subsystem level submit only a requirements verification matrix card to the subsystem IPT lead and NASA lead RT engineer. (The responsible test organization maintains the as-run test procedures). No STR or DR required.
- For inspections, analyses, and simulation verification submit the final report to the project chief engineer and lead RT engineer, in addition to the requirements verification matrix card.
- AFRC project personnel shall review the requirements of verification matrix cards to ensure requirements have been satisfied.

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Requirements Verification Matrix Card



	SCEPTOR Red	uirements Verification	on Matrix Card			
Organization:					Date:	
Requirement #	Requirement Statement	Verification Method (Inspection, Analysis, Test, Demo, Sim)	Document #	Verification Step(s)	Verified by:	Project Concurrence:

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System and Subsystem Test and Verification 7

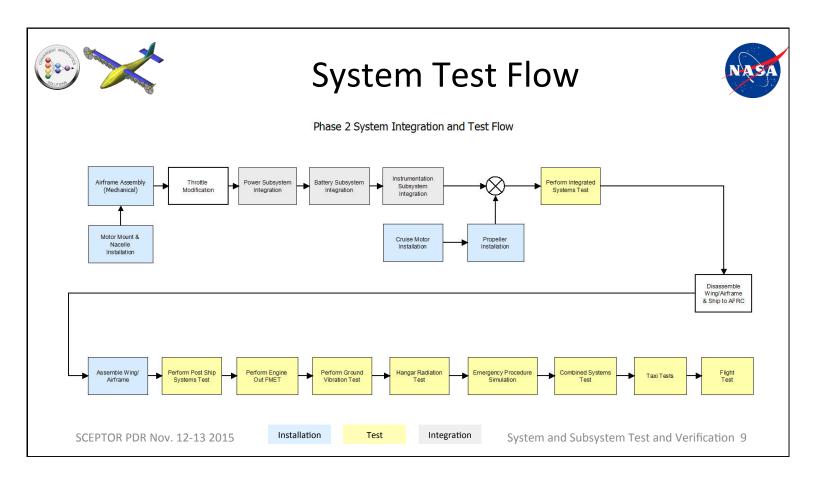


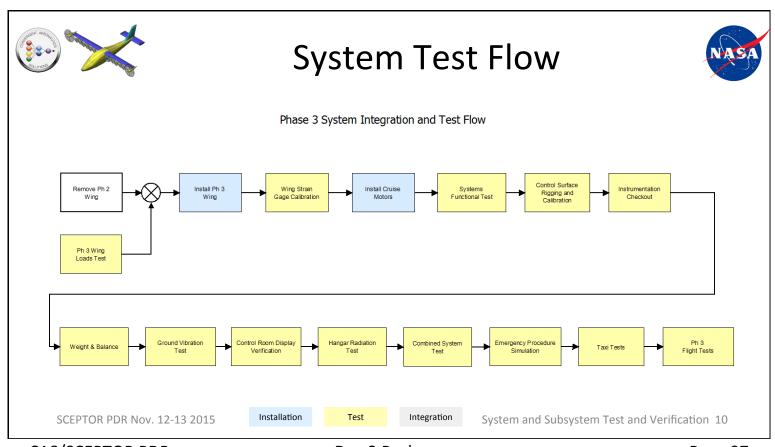
Test Inspection & Calibration



- Inspectors are required for running test procedures
 - Can be NASA or Contractor/Subcontractors
- Inspectors shall be independent from the test team, and preapproved by the IPT lead
- Metrology/Calibration
 - Calibrated tools required for tests that require measurements
 - Equipment shall be listed with cal due dates on procedures

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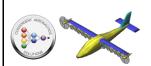
Issues & Resolutions



Issue	Resolution Plan
Subcontractor unidentified – test logistics not addressed	Select subcontractor asap

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System and Subsystem Test and Verification 11



Go Forward Plan



- Sign off test plan
- Develop test details and assign responsible organizations for conducting tests

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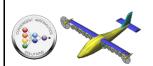




FLIGHT OPERATIONS OVERVIEW

Flight Operations
Aric Warner

aric.d.warner@nasa.gov



PHASE II



- Tecnam to be delivered to contractor/integrator
 - Shipped from Italy to Los Angeles
 - Trucked from Los Angeles to contractor
- AFRC to work with the contractor/integrator to modify the aircraft with electric motors on stock Tecnam wing.
- Aircraft will undergo functional testing at contractors facilities.
- Aircraft will be disassembled and trucked to AFRC where it will be re-assembled and be functionally tested again.
- Aircraft will be entered into NAMIS

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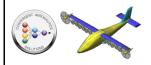
PHASE II GROUND TESTING



- V &V testing for score
- GVT
- Weight and Balance

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Flight Operations Overview 3



PHASE II TAXI TESTING



- Ground handling using differential brakes, differential throttles, rudder, and nose wheel steering
- Ground testing to determine the dynamics of an engine loss (determines how quickly an engine will go from thrust producing to drag producing, and how quickly a propeller can be feathered)

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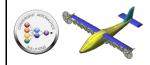
PHASE II FLIGHT TESTING



- Flights to be conducted with in the R2508 complex
 - Lakebed is a safety mitigation
- All test points to be flown within the flight envelope of the stock Tecnam
- Control room
- Chase
 - T-34
 - Where appropriate

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Flight Operations Overview 5

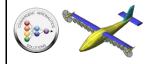


PHASE III



- Flight motors removed from Phase II wing for reinstallation on Phase III wing
- Stock wing removed from aircraft at AFRC
- Phase III Wing delivered from manufacturer and mated to fuselage
- Motors installed
- Systems installed

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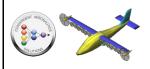
PHASE III GROUND TESTING



- V&V testing
- GVT
- Wing Loads Test
- Weight and Balance

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Flight Operations Overview 7



PHASE III TAXI TESTING



- Similar to Phase II
- Phase II taxi testing will heavily influence and shape
 Phase III taxi tests

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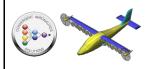
PHASE III FLIGHT TESTING



- Flights to be conducted with in the R2508 complex
 - Lakebed is a safety mitigation
- Control room
 - Monitored by appropriate disciplines
- Chase
 - Where appropriate

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Flight Operations Overview 9



MOVING FORWARD TO CDR



- Chase plan
- Life support
- Mission rules
- Go & No-Go
- Comm Plan
- Emergency Procedures
- Approved Flight Manual Redlines/Updates
- Control room display

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Preliminary Hazard Analysis Review

System Safety

Phil A. Burkhardt/661-276-3277 phillip.a.burkhardt@nasa.gov





SCEPTORPreliminary Hazard Summary

In I Human Fower ID fing (Phase III) Wing ID silure Vehicle ID iber Vehicle ID System Failure (Phase III) Wing ID ic Control ID ic Vehicle IE ints (Phase II) Vehicle IE ints (Phase III) Wing ID g Takeoff Performance ID		<u> </u>	Hazard Categories	tegories
Power ID Wing ID Vehicle Vehicle Vehicle Vehicle Vehicle ID Power Control Vehicle IE Vehicle ID Performance ID	Preliminary nazaro	<u>_</u>	Human	Assets
Wing I D Power I D Vehicle Vehicle Vehicle I D Power Control Vehicle I E Vehicle I E Wing I D Performance I D	CEPT - PH1 Aircraft Battery Fire	Power	<u>a</u>	Q
Power ID Vehicle Vehicle Vehicle ID Vehicle ID Power Control ID Vehicle Vehicle IE Vehicle IE Vehicle Vehicle IE Vehicle Vehicle IE ID Vehicle IE ID Vehicle IE ID Vehicle ID Vehicle Vehicle IE ID Vehicle ID Vehicle Vehicle ID Vehicle	CEPT - PH2 Structural Failure of Wing (Phase III)	Wing	<u>a</u>	Q II
Vehicle Vehicle Vehicle Vehicle Vehicle I D Control I D Vehicle I E Wing I D Performance I D	CEPT - PH3 Traction Power Bus Failure	Power	<u>a</u>	Q II
Vehicle Vehicle Vehicle ID Power Control ID Vehicle Vehicle IE Wing ID Performance ID	* CEPT - PH4 Facility Service Faults	Vehicle		
Vehicle Vehicle Power ID Control ID Vehicle IE Wing ID Performance ID	* CEPT - PH5 Inclement Weather	Vehicle		
illure (Phase III) Power Control Vehicle Vehicle II) Wing I D Wing I D Performance I D	* CEPT - PH6 Exposure to Carbon Fiber	Vehicle		
Control I D		Wing	<u>a</u>	Q II
Control ID	* CEPT - PH8 Uncommanded Thrust	Power		
Vehiclenase II)VehicleI EWingI DoffPerformanceI D	CEPT - PH9 Inadequate Stability and Control	Control	<u>a</u>	Q II
vehicle IE Wing ID off Performance ID	* CEPT - PH10 Weather out of limits	Vehicle		
Wing ID off Performance ID	CEPT - PH11 Failure of Motor Mounts (Phase II)	Vehicle	Ш_	=
Performance I D	CEPT - PH12 Whirl Flutter (Phase II & III)	Wing	Q I	Q II
	CEPT - PH13 Loss of Thrust During Takeoff	Performance	<u> </u>	Q II

^{*} Preliminary Hazard Requires Analysis

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Preliminary Hazard Analysis Review 2



SCEPTORPreliminary Hazard Summary

	F C -	Hazard C	Hazard Categories
Freiimiary nazaru	<u>-</u>	Human	Assets
CEPT - PH14 Loss of Avionics Power Buses	Power	≡	=
CEPT - PH15 Propeller Separation	Performance	O.	Q II
* CEPT - PH16 Inadequate Warning, Caution and Advisory	Vehicle		
CEPT - PH17 Battery Mount Failure	Vehicle	E	=
CEPT - PH18 Abrupt Asymmetric Thrust	Control	Q	Q II
* CEPT - PH19 EMI/EMC Interference	Power		
CEPT - PH20 Landing Gear Structural Failure	Vehicle	Q III	Q II
* CEPT - PH21 Propulsion System Component Failure	Power		
* CEPT - PH22 Pilot Egress	Vehicle		
* CEPT - PH23 Cockpit Air Contamination	Vehicle		
CEPT - PH24 Inadvertent Cruise Motor Propeller Rotation	Power	프	≡
* CEPT - PH25 Instrumentation Pallet Mount Failure	Vehicle		

^{*} Preliminary Hazard Requires Analysis

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Preliminary Hazard Analysis Review 3



Human Safety Hazard Action Matrix (HAM) Residual Risk **SCEPTOR**Preliminary Hazards

		Pr	Probability [Pr] Estimations	ions	
Injury Severity Classifications	A: Expected to occur (Pr > 10 ⁻¹)	B: Probable to occur (10 ⁻¹ > Pr > 10 ⁻²)	C: Likely to occur (10 ⁻² > Pr > 10 ⁻³)	D: Unlikely to occur (10 ⁻³ > Pr > 10 ⁻⁶)	E: Improbable to occur (10-6 > Pr)
I: Catastrophic				PH1, PH2, PH3, PH7, PH9, PH12, PH13, PH15, PH18	PH11, PH17, PH24
II: Critical					
III: Minor				PH20	PH14
IV: Negligible					
	AFRC Policy: Human S Center Director approv	AFRC Policy: Human Safety Primary Risks are NOT Accepted at the Center level. When considered, risk acceptance requires Center Director approval and will normally require higher authority approval. These are "Accepted Risks" only by exception.	T Accepted at the Center lev igher authority approval. Th	/el. When considered, risk ese are "Accepted Risks" o	acceptance requires
	Risk acceptance requir	Risk acceptance requires Center Director approval. These are "Accepted Risks".	These are "Accepted Risks".		
	Risk acceptance requir	Risk acceptance requires Project Manager approval.			

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Preliminary Hazard Analysis Review 4



SCEPTOR

Loss of Asset/Mission Hazard Action Matrix (HAM) Res*idual Risk* Preliminary Hazards

Injury			Pr	Probability [Pr] Estimations	ions	
рн1, рн2, рн3, рн7, рн9, рн12, рн13, рн7, рн9, рн12, рн13, рн12, рн13, рн12, рн13, рн12, рн13, рн15, рн18, рн20	Injury Severity Classifications	A: Expected to occur (Pr > 10-1)	B: Probable to occur (10 ⁻¹ > Pr > 10 ⁻²)	C: Likely to occur $(10^{2} \ge Pr > 10^{3})$	D: Unlikely to occur (10 ⁻³ > Pr > 10 ⁻⁶)	E: Improbable to occur (10 ⁻⁶ > Pr)
PH1, PH2, PH3, PH7, PH9, PH13, PH9, PH13, PH13, PH13, PH16,	I: Catastrophic					
	II: Critical				РН1, РН2, РН3, РН7, РН9, РН12, РН13, РН15, РН18, РН20	PH11, PH17, PH14
IV: Negligible	III: Minor					PH24
	IV: Negligible					

AFRC Policy: Human Safety Primary Risks are NOT Accepted at the Center level. When considered, risk acceptance requires Center Director approval and will normally require higher authority approval. These are " Accepted Risks" only by exception .
Risk acceptance requires Center Director approval. These are "Accepted Risks".
Risk acceptance requires Project Manager approval.

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Center wide procedures and trained

personnel (F, I, J)



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Hazardous Act or Condition	Causes	Effects	Hazard Cat Human	Hazard Cat Assets		Mitigations
CEPT- PH1	A. Cell design flaw	 Loss of power 	<u> </u>	Q II	1. Envir	Environmental lot testing of cells (A, B)
Aircraft Battery	B. Cell manufacturing Defect	 Ejection of hazardous 			2. Selec	Select cells and manufacturer with proven
Fire	C. Cell Aging	material			desig	design and fabrication process (A, B)
	D. Battery packaging design flaw	 Cockpit contamination 			3. Tracl	Track cell performance throughout battery
	E. Battery pack manufacturer defect	 Damage or loss of 			lifeti	lifetime (A, B, C, H, I)
	F. External/environmental abuse of	aircraft			4. Syste	System design will protect cells from external
	cells (Thermal/Mechanical)	 Damage to ground 			short	shorting, and physical damage
	G. Over charging (current or voltage)	assets			(F, I, J)	(T
	H. Battery exceeds temperature	 Injury or death 			5. Valid	Validate charger performance and safeguards
	limits (operation/storage)	personnel			befo	before use with batteries (G)
	I. Battery structure degraded by				6. Restı	Restrict cell operating and storage
	mechanical abuse				envir	environment and ensure environmental limits
	J. External battery shorting				are n	are maintained (F, H)
					7. Visua	Visual inspection after every charge and
					disch	discharge cycle (H, I, J)
					8. Batte	Batteries will handled in accordance with

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Hazardous Act or Condition	Causes	Effects	Hazard Cat Human	Hazard Cat Assets		Mitigations
CEPT- PH2	A. Composite	 Loss of aircraft 	٥	Q II	ij	Installation procedure/inspection (L)
Structural	delamination	control			7.	Perform pre/post flight inspections (A, B, C, F, H, I, J, K, L)
Failure of Wing	B. Defects in composite	 Damage or loss 			æ.	Design review (B, D, E, G, L)
(Phase III)	material /	of aircraft			4	Analysis review (B, D, E, G)
	manufacturing	 Damage to 			5.	Adhere to POH, operational placards and SCEPTOR procedures (D,
	C. FOD contact	ground assets				E)
	D. Divergence/Flutter	 Injury or death to 			9.	Control room monitoring of vehicle dynamics (C, D, E, H, I, J, K)
	E. Excessive loading	personnel			7.	Wing designed to specified factor of safety with positive margins
	F. Bird strike					(D, E, G, H, I, J, K)
	G. Improper loads cases				∞.	Coupon testing/documentation of composite material system (A,
	H. Nacelle/wing interface					B)
	structural failure				6	Fabrication procedure (A, B, H, I, J, K)
	 Fuselage/wing interface 				10.	Quality control process (A, B, H, I, J, K, L)
	structural failure				11.	Wings loads test (A, B, L)
	J. Control surface				12.	Wing inspection (NDI) pre/post ground test (A, B)
	attachment failure				13.	Aircraft GVT (D)
	K. Failure of attach point				14.	Taxi test (H, I, J, K, L)
	hardware				15.	Monitor BASH (F)
	L. Improper installation				16.	Chase aircraft (F, H, I, J, K, L)

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Preliminary Hazard Analysis Review 8



SCEPTORPreliminary Hazards

Hazardous Act or Condition	Causes	Effects	Hazard Cat Human	Hazard Cat Assets		Mitigations
CEPT- PH3 Traction Bus Power Failure	 A. Electrical short B. Wiring defect C. Design error D. Circuit protection component E. Installation error E. Sternal/environmental abuse 	 Loss of essential avionics power Total loss of aircraft power Motor failure Propullar governor 	<u>0</u>	Q =	1. 2 8. 4	Design avionics bus for single fault tolerance (A, B, C, D, E) Ground test (CST) (A, B, C, D, E, F, G, H, I) Grounding checks (G, H)
	(Thermal/Mechanical) G. Ground isolation fault	failure • Fire				system) (C, D, F) Quality control (B, E, I)
	H. Inadequate grounding I. Operational/procedural error	 Damage or Loss of aircraft 			6.	Design review (C) VFR operations only (J)
	J. Lightning strike	 Damage to ground assets Injury or death to personnel 			% oʻ	Perform visual inspection of system components (A, B, D, E, F) Adhere to SCEPTOR operational placards and procedures (E, F, H, I, J)

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Hazardous Act or Condition	Causes	Effects	Hazard Cat Human	Hazard Cat Assets	Mitigations
CEPT- PH7 Wing Control Surface	A. Composite delamination B. Defects in composite	 Loss of aircraft control Damage or loss of 	<u></u>	<u>Q</u> =	Adhere to POH, operational placards and SCEPTOR procedures (C, D, E)
System Failure	material /manufacturing	aircraft			2. Design review (C, D, E, F, G, H)
(Phase III)	C. Excessive wing deflection/	 Damage to ground assets 			3. Analysis review (C, D, E, F, G, H)
	binding	 Injury or death to 			4. Control room monitoring of vehicle dynamics
	D. Flutter	personnel			(C, D, E, G, H)
	E. Excessive aero loading				5. Control surface system designed to specified
	F. Improper load cases				factor of safety with positive margins
	G. Failure of attachment point				(B, C, E, F, G, H)
	hardware				6. Coupon testing/documentation of composite
	H. Flap actuation system failure				material system (A, B, G)
	I. Improper installation				7. Aircraft GVT (A, B, C, D, F, G, H, I)
	J. FOD intrusion				8. Taxi Test (C, D, G, H, I)
					9. Chase Aircraft (C, D, G, H)
					10. Wings loads test (A, B, C, E, F, G, H, I)
					11. Quality control process (A, B, G, H, I, J)
					12. Fabrication procedure (A, B, G, H, I)
					13. Installation procedure/inspection (I)
					14. Control surface inspection (NDI) pre/post
					ground test (A, B, D, E, F, I)

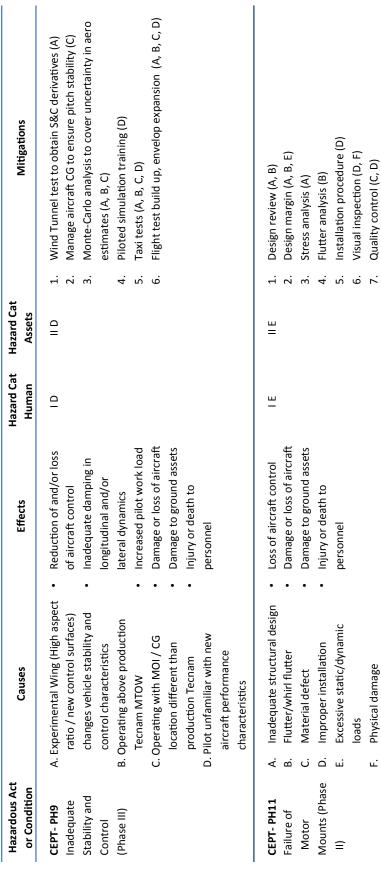
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Preliminary Hazards



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Preliminary Hazard Analysis Review 10

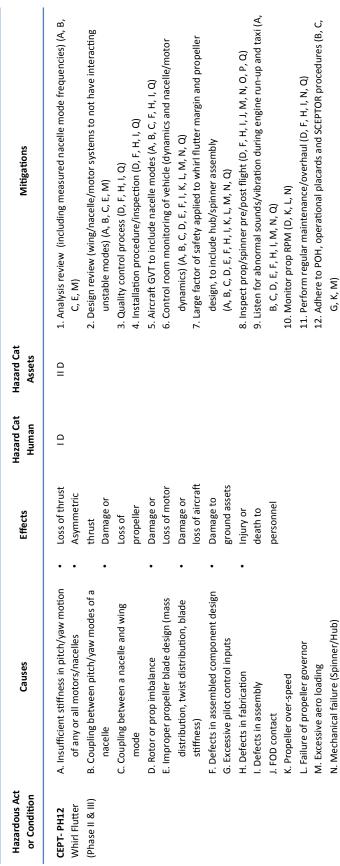
Ground tests (to include motor/propeller dynamic

balancing) (A, B, C, D, E, F)



SCEPTOR

Preliminary Hazards



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Q. Improper Installation

O. Ground strike

P. Bird strike

Preliminary Hazard Analysis Review 11

16. Taxi test (A, B, C, D, E, F, H, I, K, L, M, N, Q)

15. Chase Aircraft (B, C, J, N, P, Q)

configuration on test stand (A, B, D, E, F, H, I, K, L, M, N, Q) 14. Perform motor/propeller over-speed testing utilizing flight

13. Motor controller design to limit RPM (B, C, K, L, M)





Hazardous Act or Condition		Causes	Effects	Hazard Cat Hazard Cat Human Assets	Hazard Cat Assets		Mitigations
CEPT. PH13 Loss of Thrust During Takeoff (Phase III)	е в С С в	A. Failure in power system B. Failure in electric motor C. Failure of motor controller D. Failure in propeller E. Failure of propeller governor	 Asymmetric thrust (if failure affects single propulsor) Complete loss of thrust (if failure affects both propulsors) Loss of vehicle control Damage or loss of aircraft Damage to ground assets Injury or death to personnel 	<u>_</u>	1 D S S S S S S S S S S S S S S S S S S	Designed propulsion sy to provide partial takec B, C) Design review (A, B, C) Use COTS propellers/gc certificate (D, E) Environmental testing Motor propeller dynam Taxi test (A, B, C, D, E) Flight test of propulsion	 Designed propulsion system for single-fault tolerance, able to provide partial takeoff power in event of single fault (A, B, C) Design review (A, B, C) Use COTS propellers/governors with an FAA type certificate (D, E) Environmental testing of propulsion system (A, C) Motor propeller dynamics balancing (B, D) Taxi test (A, B, C, D, E) Flight test of propulsion system (Phase II) (A, B, C, D, E)

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Hazardous Act				240.297	Hazard Cat	Hazard Cat	
or Condition		Causes		בוופרוי	Human	Assets	IVII LIBATIONS
CEPT- PH14	Ä	A. Traction battery	•	Loss of	=	= E	1. Design review (F)
Loss of		system failure		instrumentation			2. Backup emergency battery powers avionics essential
Avionics Power	В.	Avionics DC		system			bus (A, B, C, D, E)
Buses		converter failure	•	Loss of cockpit			3. Maintaining stock Tecnam bus architecture
	ن	C. Avionics/electrical		instruments			(redundancy, isolation and protection) (A, B, C, D, E)
		component fault	•	Loss of throttle			4. Audio/visual alarm to alert pilot of degraded system
	<u>.</u>	Instrumentation		control			condition and potential hazard (A)
		system fault	•	Loss of propeller			
	ш	Faulty wiring		pitch control			
	Ľ.	Inadequate design	•	Loss of flap control			
			•	Loss of rudder trim			
				control			
			•	Damage of aircraft			
			•	Injury to personnel			







Hazardous Act or Condition	Causes		Effects	Hazard Cat Human	Hazard Cat Assets		Mitigations
CEPT- PH15	A. Composite/wood delamination	•	Loss of motor thrust	0	Q II	τi	Inspect prop/spinner prior to flight (A, B, D, L, M)
Propeller	B. Defects in composite/wood/	•	Asymmetric thrust			7	Listen for abnormal sounds/vibration during engine run-up and
Separation	metal/fasteners	•	Loss of aircraft control				taxi (A, B)
	C. Fatigue/End of Life	•	Structural failure of			3.	Monitor prop RPM (E, J)
	D. Improper installation on		nacelle/motor mount			4	Perform regular maintenance/overhaul (C)
	attachment hardware	•	Damage or loss of			5.	Adhere to SCEPTOR operational placards and procedures (D, F, N,
	E. Propeller over-speed		aircraft Loss of aircraft				(0
	F. FOD contact	•	Damage to ground			9	Implement emergency motor power shut-down
	G. Excessive vibration		assets				(E, G, H, I)
	H. Flutter	•	Injury or death to			7	Motor controller design to limit RPM (E)
	I. Unbalanced prop		personnel			∞i	Fabricate propellers with high factor of safety and perform over-
	J. Variable pitch/constant speed						speed testing (A, B, E)
	system failure					6	Use COTS components when available with substantiated safety
	K. Excessive aero loading						margins (A, B)
	L. Spinner failure					10.	Control room monitoring of vehicle dynamics (G, H, I)
	M. Hub failure					11.	Motor/propeller dynamic balancing
	N. Ground strike						(A, B, D, G, H, 1, 1, L, M)
	O. Bird strike						
	P. Inadequate design (new motor/ propeller attach point)						

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Hazardous Act or Condition		Causes		Effects	Hazard Cat Human	Hazard Cat Assets		Mitigations
CEPT- PH17	خ	A. Inadequate design	•	Loss of power	<u> </u>	= = =	1.	1. Design review (A)
Battery Mount Failure	В.	Material defect	•	Loss of TM			5.	Design margin (A, D)
	ن	C. Improper	•	Loss of aircraft control			æ.	Stress analysis (A, D)
		installation	•	Damage or loss of			4.	Installation procedure (C)
	Ö.	D. Excessive loads		aircraft			5.	Visual inspection (C)
			•	Damage to ground			9.	Quality control (B, C)
				assets			7.	Ground tests (A, B, C, D
			•	Injury or death to				
				personnel				





Hazardous Act or		Causes		Effects	Hazard Cat	Hazard Cat	Mitigations
CFPT- PH18	⋖	Power system fault		Loss of aircraft	2	Q I	1 Motor/power system redundancy (A. B. C. D)
Abrupt Asymmetric	ъ.			control	l	! :	2. Flight Test – Phase I & II
Thrust (Phase III)		mechanical system	•	Damage or loss of			(A, B, C, D, E, F, G, H, I)
		failure		aircraft			3. Design review (A, B, C, D, E, F)
	ن	Single speed	•	Damage to ground			4. Design margin (B, E)
		controller failure		assets			5. Stress analysis (B, E)
	Ö.	Throttle system	•	Injury or death to			6. Pilot warning light, audible alarm (A, C, D, I)
		malfunction		personnel			7. Auto shutdown of opposite side cruise motor (if
	ш	Power train					analysis determines necessary) (A, B, C, D, E, F, G,
		structural failure					Н, 1)
	щ.	Propeller pitch					8. Control room monitoring of health & status
		controller failure					(A, B, C, D, E)
	9	Inadvertent prop					9. Piloted simulation training
		feather					(A, B, C, D, E, F, G, H, I)
	ij	Propeller damage					10. Environmental acceptance test (A, C, D)
	<u>-</u> :	Erroneous					11. Qualification test (A, B, C, D, E)
		command					12. CST (A, B, C, D, E, F, G, H, I)
							13. Taxi test (A, B, C, D, E, F, G, H, I)

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Hazardous Act or Condition		Causes	Effects	Hazard Cat Human	Hazard Cat Assets	Mitigations
CEPT- PH20	Ą	A. Increased takeoff/	 Loss of propellers 	Q III	QII	1. Adhere to operational placards and SCEPTOR
Landing Gear		landing speed	 Scattering debris 			procedures (A, B)
Structural Failure	B.	Increased rate of	 Damage or loss of 			2. Installation of nose wheel shimmy dampener (D)
(Phase II & III)		descent	aircraft			3. Maintain aircraft CG within specifications (E)
	ن	Exceed MTOW	 Injury to personnel 	el e		4. Minimize sink rate on landing (B, C, E)
	Ō.	Nose wheel				5. Analysis review (A, C, D, E)
		shimmy				6. Taxi test (A, D)
	ш	Excessive loading				
CEPT- PH24	Ą	A. Inadequate design	 Damage to 	=	≡ E	1. Design review (A, C, D)
Inadvertent Cruise	B.	Operator / pilot	propellers			2. Adhere to POH, operational placards and
Motor Propeller		error	 Damage to aircraft 	£		SCEPTOR procedures (B)
Rotation	ن	C. Controller fault	 Scattering debris 			3. Multiple actions required to energize system
	Ö.	GSE fault	 Damage to ground 	q		(A, B, C, D)
	ш	Wind	assets			4. Propeller tether/tie-down (E)
			 Injury or death to 			5. SCEPTOR procedures to include safety critical
			personnel			warnings/cautions (B, C, D, E)
						6. System to be operated by only trained
						personnel only (B)
700 CL CL N AGA ACTATOS		7 FOC C				